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ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

Founded by Edmund H. Fulling

VOL. 14 OCTOBER-DECEMBER, 1960 NO. 4

NEWS ITEMS

Lab Manual for Economic Botany Course

Economic Botany has been taught at Harvard University since 1876. *Biology 104,* now called *Plants and Human Affairs,* a half-course open to properly qualified undergraduate and graduate students at Harvard University and Radcliffe College, is taught by Professor Paul C. Mangelsdorf and Dr. Richard Evans Schultes in the Laboratory of Economic Botany at the Harvard Botanical Museum. It comprises a consideration of the plants which are used by man (exclusive of ornamentals), their origins and history, botanical relationship and their roles in prehistoric and modern cultures and civilizations.

The laboratory work in this unique course has long attracted the attention of botanists and anthropologists, many of whom have requested copies of the mimeographed laboratory outlines for guidance or use in their own teaching.

Now for the first time the Laboratory Manual for Biology 104 has been published in offset form (set by ATF typesetter) in a saddle-stitched paper-bound edition. The Manual is divided into 12 weekly exercises as follows: I. Plant Classification and Economic Botany; II. Food Plants—1 (Sugars, Cereals and other Starch Plants); III. Food Plants—2 (Legumes, Nuts, Vegetables and Fruits); IV. Fibre Plants; V. Essential Oil Plants; VI. Caffeine Plants; VII. Stimulant and Narcotic Plants; VIII. Drug and Poisonous Plants; IX. Wood, Cork and Economic Fossil Plants—1, Archaeological Plant Materials—2; X. Fatty Oil and Wax Plants; XI. Rubber, Gum and Resin Plants; XII. Tannin and Dye Plants and Paper.

The 64 pages of text are supplemented by 2 blank sheets at the end of each exercise; a chart showing phylogeny of the Plant Kingdom; 4 Ames Charts (on which much of the laboratory teaching is based) showing the Engler-Prantl System of the Gymnospermae, Monocotyledonae, Archichlamydeae and Metachlamydeae illustrated by important economic plants; and drawings of gymnospermous and dicotyledonary wood anatomy.

Since so many requests for the laboratory outlines have come in the past, the Botanical Museum has decided to offer for sale this Manual at a cost of $2.50 a single copy or $2.00 a copy for orders of ten or more. Order from and make cheques payable to the Botanical Museum of Harvard University, Cambridge, Massachusetts.

Schultes, R. E. & A. F. Hill: "Plants and Human Affairs" (Laboratory Manual for Biology 104, Harvard University) Published by Botanical Museum of Harvard University, Cambridge (1961).

New Organization

Studiengesellschaft zur Erforschung von Meeresalgen E.V.

The "Studiengesellschaft," an international organization was recently established to further the scientific study and utilization of marine algae. At a recent meeting of the organization, Mr. Prof. Dr. Tore Levring, of Göteborg, was elected president, and Mr. Heinz A. Hoppe, Hamburg, was elected chairman. At the meeting a "scientific council" for coordination of the activities of the organization was formed, with Mr. Otto Schmid, Hamburg, in charge.

One of the main activities of the Studiengesellschaft zur Erforschung von Meeresalgen is to act as a center for documentation of seaweed research and utilization. Botanica Marina, now in its first volume, is the official publication of the organization. The Studiengesellschaft invites the participation of any interested scientist. Inquiries should be made to the organization at Postfach 393, Hamburg 36, Germany.

Tapping Our Heritage of Ethnobotanical Lore[1]

RICHARD EVANS SCHULTES[2]

The Space Age is upon mankind. It beckons to incredibly strange and promising areas of new discovery. It is wonderful to be alive at such a time and to dream about what may be ahead in learning. Some of us hope, however, that space study will not lessen the attention given to the many fields anchored on this small globe. One of the many fields of this kind is investigation of the Plant Kingdom as it relates to the liberation of man from pain and sickness.

How are we to proceed in furthering our understanding of this phase of the plant sciences? There are three main methods which may be followed: one is basically bibliographic; two are concerned primarily with field work. Both the bibliographic and the field methods may sometimes of necessity or advantageously be interwoven. These three paths of research are: 1) a survey of the literature for reports of therapeutic uses of or beliefs about plants; 2) the chemical investigation of definite floras or of chosen families or genera of plants in the search for new active principles; 3) the field study of ethnobotany amongst primitive peoples.

Primitive man everywhere lived close to nature. An important—yes, an essential—part of his equipment was a deep and discerning acquaintance with the flora around him. This acquaintance led inevitably to experimentation. From the experimentation there gradually accrued a knowledge of properties, useful and harmful, of many plants. And this knowledge, tested by time, grew into an integral part of culture and was passed on from generation to generation. Some of it is still with us to-day. It may not, however, be here long.

Civilization is on the advance in many, if not most, primitive regions. It has long been on the advance, but its pace is now accelerated as the result of world wars, extended commercial interests, increased missionary activity, widened tourism. The feverish road-building in Latin America gives us an example of how fast penetration is proceeding. The fact that what our political leaders euphemistically call "progress" is often synonymous with destruction of natural resources is beside the point here. What does concern us is the progressive divorcement of primitive peoples to a greater or lesser degree from dependence upon their immediate environment. The arrival and cheap availability of the aspirin pill, for example, seems often to start an astonishing disintegraton of native medical lore. The rapidity of this disintegration is frightening—I doubt that even the field anthropologist is fully aware of its pace. That the aspirin may be more beneficial than herbs and magic is not ours to consider here. What does interest us academically and practically is how to salvage some of the medico-botanical lore before it shall have been forever entombed with the culture that gave it birth.

ETHNOBOTANY—the study of plants as they relate to human affairs, especially amongst primitive peoples—is not new. The world's literature from earliest written records is replete with references to useful or harmful plants, especially those endowed with supposedly curative powers. And some cultures, such as the Peru-

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[1]Presented at First Annual Symposium of The Society for Economic Botany; *Integrated Research in Economic Plants.* Purdue University, Lafayette, Indiana. May 22, 1960.

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vian, which had not invented writing, have left us a rich heritage of archaeological material from which much may be gleaned. The Sumerian ideograms, dating back to 4000 B.C., refer to plant uses. The Ebers Papyrus, written in Egypt about 1500 B.C., is a rich ethnobotanical manuscript. The oldest Chinese source seems to be Erh-ya, a book on nature studies, written in 3000 B.C.; other ancient Chinese sources are the Book of Poems, the Svu-ching, of 1000 B.C. and the Ben-tsao, an early herbal, dating from 1250 A.D. In India, the sacred Vedas (1500-1000 B.C.) give us many references to plant uses. The classical world of the Mediterranean, set in a not-too-rich flora, made extensive use of the Plant Kingdom in alleviating and presumably curing human ills. The medico-botanical lore of the cultures of Asia Minor, Greece and Rome, including that of the Biblical peoples, is too well known to detail here. As a result of the studies to interpret Dioscorides and other classical writers which occupied the attention of European doctors and botanists until about 1600, probably little of an ethnobotanical nature written by the Greeks escaped the attention of the Europeans of the Middle Ages.

The discovery of the New World led to more than extension of geographic knowledge. Reports of the plants of the new lands and their curious uses helped free herbalists from slavish repetition of the classical writers. The 16th and 17th Centuries are especially rich in writings with references to New World plants, ranging from incidental but sometimes highly significant references in reports of travellers, missionaries or explorers to extensive volumes by specialists on natural history. These are too numerous to enumerate. The conquest of Mexico, for example, gives us outstanding examples of this kind of literature. Some of the most valuable references to Aztec medicinal plants appear in the writings of the cleric Sahagún, whose pen covered a vast expanse to create the work called "Historia General de las Cosas de Neuva España." These old clerics had an orderly method which allowed them to cover, even though with extreme prejudice, an astounding range of topics. Many similar works, though few so extensive, came out of Mexico of the post-conquest years, and these have not yet really been adequately studied. There is little, however, which can compare in thoroughness, accuracy and detachment to the "Nova Plantarum, Animalium et Mineralium Mexicanorum Historia," written between 1570 and 1575 by Dr. Francisco Hernández, physician to the King of Spain. Accurate though stylized drawings of plants are accompanied by extremely detailed accounts of the plants and their uses. There is a wealth of information here which still bears investigation. In addition to the old writings that did see publication, there are manuscripts which, because they have never been printed, are even more worthy of investigative study.

How important it is that one of our starting points in studying medico-botanical lore lies in a critical examination of this published and unpublished emporium may be illustrated by two recent advances in Mexican ethnobotany. These advances, had the reports of the old chroniclers been taken seriously by modern investigators, would not have been recent.

Time has frequently erased, through extinction or absorption, the cultures and peoples on which old reports were based. This is, however, not always the case. In a few fortuitous instances, descendants still live in the same region and are culturally little changed. If the peoples and cultures are gone, then, of course, no amount of field work today can uncover corroboration of old records of plant uses. On the other hand, if the peoples and cultures be still available for study, then careful field investigation may uncover similar uses persisting into the present, and we may oftentimes learn much more

by modern studies than the old chroniclers were able to write down for posterity. This is borne out in our experience in Mexican ethnobotanical studies, and especially in two cases which we shall consider now.

Sahagún and other non-technical writers reported the use as a sacred hallucinogen of a lentil-like seed borne on a climber and called *ololiuqui* amongst the Aztecs. One edition of Sahagún's writings pictures a twiner with a swollen root. Most of the chroniclers were men of the church and they railed violently against this "diabolic seed" valued by the pagan Indian as a divine messenger capable of taking man's mind to spirit realms. In his more technical manner, Hernández described ololiuqui in detail, pointing out its therapeutic and psychotomimetic use and giving us a drawing which unmistakenly puts ololiuqui into the Convolvulaceae, the family of the morning glory. Notwithstanding the insistence of several Mexican botanists in the past century that ololiuqui was, in fact, referable to the convolvulaceous *Rivea corymbosa,* no corroboration came from field work. In 1915, the American economic botanist Safford categorically stated that ololiuqui could not be referred to the Convolvulaceae but that it must represent *Datura meteloides,* a well known narcotic employed in Mexico and the American Southwest as an hallucinogen. Safford argued that no narcotic member of the Convolvulaceae was known; that the intoxication induced by ololiuqui was similar to that induced by *Datura;* and that the convolvulaceous flower, trumpet-shaped, might pass superficially for a flower of *Datura.* Safford went so far as to doubt the value of certain early Mexican accounts of ethnobotanty when he stated: "A knowledge of botany has been attributed to the Aztecs which they were far from possessing. . . . The botanical knowledge of the early Spanish writers, Sahagún, Hernández, Ortega and Jacinto de la Serna, was perhaps not much more extensive: their descriptions were so inadequate that even to the present day the chief narcotic of the Aztecs, *ololiuqui,* which they all mention, remains unidentified."

It was not until the early 1940's that, on the basis of specimens of *Rivea corymbosa* which I discovered growing in the dooryard of a curandero in northeastern Oaxaca, modern field work vindicated the accuracy of the observations of the early Spanish chroniclers. So far as I know, chemical examination of *Rivea corymbosa* has not yet uncovered the active principle, but work is still being continued, and the results may turn out to be of a more far-reaching nature than we might normally expect.

I would also cite here the interesting case of the sacred psychotomimetic mushrooms of Mexico. As with ololiuqui, the early chroniclers spoke of their use in religious rites as a kind of sacrament inducing visual hallucinations. Called *teonanacatl* or "flesh of the gods," these fungi drew special wrath and persecution from ecclesiastical authorities. Half a dozen chroniclers mentioned them. One of these, Sahagún, has unusually detailed descriptions of the intoxication; and one of his writings published crude illustrations of the narcotic mushrooms. Hernández wrote of three kinds which the natives worshipped.

Notwithstanding the relatively numerous and forceful Spanish reports, nothing was known of the identity of the mushrooms until recently. Persecution drove the mushroom cult into hiding. The first attempt to identify teonanacatl was made in 1915 when Safford asserted that it was really the peyote cactus. The dried, brown, discoidal head or "button" of *Lophophora Williamsii,* he wrote rather unconvincingly, resembled "a dried mushroom so remarkably that at first glance it will even deceive a mycologist." As with ololiuqui, Safford's outstanding reputation stamped

his views with authority and, despite the denials of Reko, a physician and amateur botanist of Mexico, his conclusions were widely accepted.

It was not until the 1930's that the first steps towards identification came. Weitlaner, an engineer of Mexico City, collected specimens in Oaxaca; though poorly preserved, these were identified at Harvard as representing the mushroom genus *Panaeolus*. The next year, Reko and I found *Panaeolus sphinctrinus* and *Stropharia cubensis* employed by the Mazatecs of Oaxaca, and I published a note on the first of these as apparently the major hallucinogenic mushroom of the region. My work then took me to the Amazon for twelve years, and I never returned to Oaxaca to follow up the research. Perhaps this was providential. Fifteen years later, Mr. R. Gordon Wasson and his wife, keen amateur mycologists, read my papers and began a series of meticulously planned expeditions to Oaxaca. He sensed the need for an intensive, all-inclusive study of the sacred mushrooms and their uses, so he enlisted the collaboration of specialists. The resulting research, woven by Wasson into an intricately interrelated whole, will long hold a high place as an outstanding model of what concerted and thoroughly executed ethnobotanical investigations can accomplish. The Wasson group, including the French mycologist, Heim and the Swiss chemist, Hofmann, has established the use as hallucinogens of seven species and varieties of mushrooms belonging to the genera *Conocybe*, *Psilocybe* and *Stropharia*. Their studies covered botany, ethnology, archaelogy, linguistics, musicology, religion and chemistry. The chemical studies have established the presence in *Psilocybe* of an active principle, psilocybine, an acidic phosphoric acid ester of 4-hydroxydimethyltriptamine, allied to such compounds as bufotenine and serotine; and the first known naturally-occurring indole derivative containing phosphorus. The work on these mushrooms has opened up long vistas in many fields of research.

The important consideration for us at this point, however, is the timing of research into ololiuqui and teonanacatl. With the rapidity of penetration and acculturation in Mexico, it is certain that we have arrived in the nick of time. I am convinced that another quarter of a century might have doomed to extinction much if not all of the ethnobotanical lore surrounding the sacred mushrooms in many if not all of the mountain areas where it still flourishes. It has lain available to us for 400 years had we but taken seriously the early reports. How fortuitous our arrival! Will it be as fortuitous with other perhaps equally fascinating and rewarding medicobotanical lore? Few of us could have been ready to accept the fantastic reports of the early writers on the unearthly effects of the sacred mushrooms. Now we know how true they were. We can no longer afford to prejudge reports of aboriginal uses of plants simply because they seem to fall beyond our limit of credence.

Notwithstanding the fact that primitive peoples do possess a valuable understanding of the properties of plants, we realize that their knowledge has been optimistically exaggerated in the past and that it must be far from complete. We could not expect it to be otherwise. It, therefore, behooves us to carry out our own phytochemical studies of the flora in general. This study is probably best done along two paths: 1) intensive examination of families and genera known to be rich in active principles—alkaloids, glucosides, resins, etc.; and 2) a systematic examination, species by species, of a random sampling of floras.

Much has been done in the study of groups rich in active principles. It is not of recent inception, but it has been greatly intensified in recent years. This intensification of research has been directed especially towards alkaloidal groups, partly

because of improved phytochemical techniques. An excellent summary, published recently by Willaman and Schubert, stresses the important advances made and points out the promise that future investigation holds. They tabulate the presence or absence of alkaloids in 250 families, stating that "about 950 alkaloids have been isolated and named from two percent of all species which have been tested for them." Similar efforts with glucosides and other principles might be equally rewarding.

The phytochemical study of every species represented in a restricted geographic area or vegetational zone would seem likewise to be a basically sound approach. It requires, however, a somewhat more concerted botanical attack and must be backed up with very extensive chemical and pharmacological laboratory facilities. A few attempts along this line of attack have been sporadically carried out. Such a survey of the flora of Queensland for alkaloids has been under way since the 1940's by Australian scientists. Similar, though more conservative, alkaloidal surveys of floras are reported for North Borneo and the Argentine. I am aware of at least one American drug company now active in this kind of research with a survey of flora of Pennsylvania and about to undertake a study of plants collected in the rich flora of Colombia in South America. The results from this type of investigation are certain to be full of surprises, such as the recent discovery in the silver maple, *Acer saccharum*, of an indole alkaloid: gramine. It may be a long while before the pieces in such a puzzle fall into place, but the method is indeed a challenging one.

Perhaps the most satisfying way of studying ethnobotany is direct investigation amongst primitive peoples. Insofar as this method is time-consuming, it is not easy, but it cannot be called difficult or hazardous. Only in the sensational books written for self-glorification by intrepid "explorer-writers" do these difficulties and hazards assume a gargantuan status. The generalized idea of the explorer is wrong. His is a job much like the bank teller's. The anthropologist or botanist willing to work and travel for long periods, or the missionary living permanently amongst natives, has unparalleled opportunities for learning something of the plant medicines of the region. And of these, perhaps, the botanist has the easiest entrée. Most natives become intensely curious at the botanist's ceaseless plant collecting. This curiosity creates a rapport between botanist and native, a common denominator leading to an easier exchange of conversation and ideas concerning plant uses.

I can, of course, speak only of the American tropics, but I do believe that similar conditions prevail elsewhere. The rather prevalent concept that witch-doctors have secrets which they guard zealously is in general unfounded. This impression results probably from the natural reticence of many natives in the presence of civilized man whom they feel to be superior. In connection with their medical practices, they may have experienced that white man's patronizing or even deprecating brush-off; and this is hardly conducive to openness in discussion. Much can be accomplished if the ethnobotanical investigator treats natives as a gentleman should. He must realize that, far from being the superior individual, he—the civilized man—is in many respects far inferior to the native in the native's own environment. In my twelve years of almost permanent residence and exploration in the northwest Amazon, I never found natives unduly reticent or resentful of any interest which I expressed in their medicinal or narcotic plants. I discovered that the farther I moved from small towns and mission stations, the more openly did the Indian discuss these matters. It went even farther than frank discussion: I very often partook of native

narcotics along with Indians in their rituals and dances and was frequently able to witness the treatment of disease by a witch doctor and to discuss it with the practitioner. The example of oral contraceptives in a case in point. Far from white man's influence, the native will discuss and point out the plants used as oral contraceptives; but within the sphere of missionary influence or commercial centres, it is absolutely impossible to discuss the question, although I strongly suspect that many of the civilized or acculturated natives know and use the plants.

It would be far beyond the scope of this short talk to consider methods of carrying out field work in ethnobotany. They vary with the region; with the kind of people and their degree of acculturation; with the wealth of the flora and our understanding of it; with the time available for the study; with the size of the investigating group; with the type and extent of training of the principal investigator.

There is one all-important condition which all good field work should demand; voucher specimens for the identification of every plant for which an important use is reported. The field of native drug plants, especially, is an example of this basic need. Much of the excellent chemical work done on various native medicinal plants during the past sixty years is valueless to-day because it cannot be repeated. No voucher herbarium specimens backed up the botanical determination of the material under analysis. In fact, the so-called "determination" was made often not by a botanist but by a chemist or even by an office executive, from a vernacular name.

There remains to say a word about the best preparation for ethnobotanical research. Outstanding contributions can be and have been made by men of various degrees of preparation in sundry fields. The anthropologist—if he pay heed to the botanical necessities of this research—may be admirably trained. I should say that the ideal training, however, would be basically botanical with ample backgrounds in ethnology and ethnography on the one hand, and in plant chemistry and pharmacology or medicine on the other. A facility in learning languages would likewise be helpful. Such a combination cannot frequently be found, and few universities now apparently look with favour on such an interdisciplinary training. But when a scientist with this or similar preparation does appear, we would be negligent if we did not make every effort to channel his research energies into the general field of study of the interrelationship between man and his plant environment.

New Crop Establishment[1]

P. F. KNOWLES[2]

As a text for my report I would like to use the words of Dr. R. D. Lewis, Director of the Texas Agricultural Experiment Station and Chairman of the President's Commission Task Group on New and Special Crops (19). "A new crop is neither a magic development nor a magic solution. It generally represents years of search, study, evaluation, adaptation and culture, deliberate development and planned promotion." My purpose is not to trace for you in detail the actual development of new crops. Rather, I intend to highlight, as I see them, the main factors involved in the successful establishment of a new crop. In conclusion I shall present some ideas indicating where botanists, using this word in a rather wide sense, fit into this picture. Forgive me if I bias my remarks toward the oil crops and toward our experience with them in California.

When I say "new crop," I am thinking primarily in terms of a crop new to the economy of a nation or area, but old in some other part of the world. This would be a crop such as hard red spring wheat a century ago, soybeans about the beginning of this century, flax in California some 30 years ago, and at the present time crops such as safflower, castorbeans, sesame, guar and ramie. I limit myself in this definition realizing that established crops may become new crops in the sense that new uses and new versions may be developed—changes in the starch components of corn might be cited as an example, or the use of guar for industrial purposes rather than for forage.

A second group of plants that I shall consider in less detail are those overlooked by neolithic man in the process of domestication. It is no accident that these are of interest primarily for pharmaceutical or industrial uses. Long ago, hunger and curiosity led primitive man to explore all species as a source of food, and perhaps as a source of stimulants. We should not overlook, however, the domestication of wild species for use as forage crops, particularly for use on the range. Considering the extent of the range in the United States, and improvements in its use, it is more than likely that the domestication of plants in our day will play its greatest role among the forage crops.

On the other hand, it may be argued that history will record modern man's greatest contribution to domestication of plants among the lower organisms. I need not repeat what has been accomplished with the antibiotics. In Germany during World War I serious consideration was given, and some research was applied, to the improvement of a yeast, *Endomyces vernalis*, as a source of oil (8). Though we are only beginning the total exploitation of the lower organisms, and though they may well be the source of products with specific properties—oils of one fatty acid, steroids of a particular type, starch of an improved molecular structure—I do not intend to consider them further here.

In considering the development of new crops for food or feed, one obvious problem presents itself. Greater use of a new crop for food or feed will displace or render surplus an equal amount of an established crop. This, of course, is unique to the economy of only a few countries. Of most interest for us at the present time, therefore, are developments in crops that might be used for industrial purposes.

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[1]Presented at First Annual Symposium of the Society for Economic Botany. *Integrated Research in Economic Plants.* Purdue University, Lafayette, Indiana, May 22, 1960.

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Actually, industry has replaced many agricultural products, in part at least, with synthetic products obtained more cheaply or in a more desirable form from the petrochemical industry. As economic botanists, our main concern is the direction our research should take to maintain industry's interest in plant products and perhaps to recover ground that has been lost.

Factors Affecting the Establishment of a Crop

As one examines the history of the development of new crops, it becomes apparent that a number of factors influence their success or failure. It is not possible to list these factors neatly in the order of their importance, because their significance varies with each crop.

(1) *Market:* It is very obvious that a market must exist for a new crop to ensure its successful development. The market for castorbeans preceded its development as a commercial crop. For the last 20 years the United States has annually used the equivalent of 250 to 300 million pounds of oil. Castor oil has had perhaps more industrial uses than any other oil, and no doubt will remain or increase in importance in the industrial economy of the Nation. It is not surprising that it should get consideration as a new crop.

Nor is it surprising that the acreage of rape in Western Canada should increase from almost none in 1950 to 629,000 in 1957 (24), when one realizes that there have been large amounts of vegetable oil imported into Canada. This shortage of vegetable oil has encouraged the development of sunflowers for oil in Canada over the last 15 years (21). On the other hand, a market is no guarantee of the success of a new crop. California uses annually the equivalent of 600,000 tons of soybeans and pays approximately $25 per ton to import them from the Corn Belt, yet it is not a commercial crop in that state (18). Yields in California are comparable with those obtained in the Corn Belt, or even better. High cultural costs —irrigation, insect control, weed control, high land rental—have been the main barriers to its development. The same costs applied to other crops such as common beans, corn, sugar beets and certain vegetables have yielded a higher return.

Even if not established in the market, a new crop's development will be aided greatly if it has certain unusual or desirable characteristics. This has been true of safflower, where the very high content of linoleic acid—some 70%—in the oil has made it of more than usual interest to industry (4, 16, 17). Industry prefers an oil that is largely of one fatty acid, because such an oil may be modified more readily for different uses. It is also interested in oils with fatty acid structure adaptable to many uses. Recent work (6, 7) USDA Utilization Laboratories is uncovering just such oils, an example being that in a species of the genus *Dimorphotheca,* the cape marigold (14). The same could be said of a search for plants bearing unusual forms of cellulose, starch or protein (15).

Where a crop must make its way into a market, as safflower has done, it is important that the market and production be kept in balance. This is no easy task. It is doubtful that safflower oil will be strongly in demand by the paint and varnish industry until it is available in large amounts, so large that the major companies will change their formulas. To change they must be assured of a continuous and abundant supply year after year, something that cannot be done for a crop not yet well established. At the same time, the oil seed processor cannot commit himself to the purchase of a large volume of safflower seed in any one year without the assurance that the oil therefrom will be purchased. This means that the market and the acreage of the crop must be developed in an orderly manner, with some balance between supply and demand. For

tunately for safflower, there has been a healthy export demand for the seed, most of the excess over domestic consumption going to Japan.

However, we cannot often depend upon an export market to serve as a cushion against overproduction. New or other domestic uses will make a new crop less vulnerable to market fluctuations. Safflower oil, while primarily of interest to the paint and varnish industry, is now being marketed as an edible oil in the United States in increasing amounts, though the volume is still small. Guar, now of increasing importance as a source of mannogalactan in the seeds used in the manufacture of superior types of paper and in textile sizings, may also be used as a green manure or cover crop in the Southwest (9). Actually, it was introduced for the latter purposes about the beginning of the last century. As an industrial crop, however, guar is still in that critical stage between limited and wide acceptance, and between limited and extensive acreage.

This balance between supply and demand is not unique to safflower and guar. Allison (1) states for ramie "This rapidly growing interest in the fiber brings us to the most difficult problem of all, as of the moment, namely, the coordination of supply and demand at this uncertain stage of development at both levels—production and use. In other words the growers do not want and cannot afford to produce it in volume before they have a definite market for it and the mill man does not feel like planning to use it until he can get as much as he may need at any time in precisely the staple length and quality he requires for his particular purpose."

While on the subject of market, it is important to remember that new crops usually do not enjoy support prices, and must compete with world prices. Except for the period when it was a strategic crop, this has been true of castorbeans. It has always been true of safflower, though there is hardly enough safflower in the world market to establish a price. A market assumes also that storage facilities will be available. This has not been a critical factor in the development of new crops in California, primarily because the companies developing these crops have anticipated and provided for their needs well in advance. With surplus supplies of many crops in warehouses, this is a facility that cannot be overlooked. Castorbeans are poisonous, so their storage and handling pose special problems.

Strange as it may seem, one of the serious market problems with certain new crops has been the disposal of the by-products. This has been true of castorbeans; the meal is poisonous and must be used for fertilizer; the meal also has allergenic properties making it uncomfortable and even dangerous for certain persons to handle. Safflower meal has a low protein content—about 19 to 20%—which has made it difficult to market in competition with cottonseed and linseed meal. In Canada rapeseed meal has contained a toxic principle which has limited its use to small amounts in animal feeds.

(2) **Acreage must be available**: It is rather unlikely that either safflower or castorbeans would have excited much interest in California in 1950 in the absence of severe acreage reductions in cotton. There is no doubt that the present low price of barley has encouraged farmers to substitute safflower. In Canada the surplus of cereal crops has increased the production of rape. Interest in sesame production in Texas is in part a reflection of surplus supplies of cotton and sorghum. Going into the past, soybeans were aided in their establishment by the acres released from oat production following the substitution of the tractor for the mule and horse. Hard red spring wheat was the best adapted crop for the surplus acres developing in the northern Great Plains following settlement. I do not intend to become involved in a discussion of the

areas of the United States or other countries where surplus production of staple crops will encourage interest in new crops in the future. Suffice it to say that the pattern of the present will most certainly extend over the next 10 years.

(3) **Subsidies for new crops**: There is no question that castorbeans benefited in their development from a minimum price guaranteed by the Federal Government because it had been declared a strategic crop during the Korean War. Acreage increased (Table I) from 7,000 in 1950 to 124,500 in 1953 with a minimum price of 9 or 10 cents per pound. It dropped to 26,600 in 1954 with a decrease in the guaranteed price to 6 cents per pound, and in 1955 to 5,100 acres with no support price. Culture of castorbeans on a commercial scale permitted the solution of many problems not possible to solve when it was grown on a small experimental scale. More was learned about the following: the area where the crop was best adapted; cultural methods; harvester design; and the dimensions of the castorbean variety which the breeder should develop.

While subsidies have aided in the development of new crops, they have not been essential. Safflower developed without its aid. In Canada, in spite of a severe drop in acreage of rape following the removal of government price supports in 1949, acreage began to increase with the interest and support of industry in 1950 (24). Both rape and safflower, however, are crops that may be handled with conventional equipment. Where expensive equipment is necessary or must be developed, the argument for government support is more valid. It is even more valid when industry is reluctant to sponsor the crop.

TABLE I

CASTOR BEAN ACREAGE IN THE UNITED STATES 1950 TO 1959[1]

Year	Guaranteed price (cents/lb)	Acreage
1950		7,000
1951	10	62,700
1952	9	97,600
1953	9	124,500
1954	6	26,600
1955		5,100
1956		4,800
1957		12,100
1958		23,300
1959		16,900

[1]1950 from Zimmerman, 1958, 1951 to 1959 from USDA Fats and Oilo Situation 188, January, 1958, and 201, March, 1960.

(4) **Sponsorship by industry**: New crops are established on a permanent basis by companies or cooperatives who are willing to provide a market for the crop, to construct or modify facilities to handle the new product, to develop markets, and to develop new uses through research. The permanent establishment of safflower has been due to one company, the establishment of castorbeans to two. Sesame and guar have benefited similarly from the support of industry. Sponsorship by industry has included the establishment of breeding programs. The companies sponsoring castorbeans and safflower have developed their own varieties. The same is true of guar (9).

(5) **Production under contract**: Because of the limited market for a new product, farmers have been reluctant to grow the new crops without some form of contract with a purchaser. This has been true of safflower, castorbeans and sesame in California; it appears to be true of these crops in other areas of the United States; and it is true of rape in Canada. These contracts may take many forms, but usually state that the buyer must take the entire crop grown on the contracted acreage, that a minimum price will be paid, with additional payments depending on the selling price of the product, and that the grower cannot hold back part of his harvest. Some financial help may be supplied to the grower during the crop year, this amount to be deducted from the price he receives at harvest. This contract form of production is not

something unique to new crops; sugar beets, many vegetables, and other specialty crops are grown in this manner.

(6) **Advisory service**: One factor that has contributed greatly to the success of a new crop in California has been some form of advisory service to farmers. Oilseed processors contracting acreages of safflower and castorbeans have had trained agronomists in contact with their growers. They have taken the initiative not only in terms of extending information to farmers but also in collating and developing information. This has given the grower greater confidence in growing the new crop, often a crop quite different from that which he is accustomed to grow. Again, this is not something new. It has been provided by most companies contracting sugar beets and vegetable crops.

(7) **Promotion**: There has been an evil connotation in the word "promoter." But whether we like the word or not, the development of a new crop will require some promotion. It will benefit from enthusiastic but honest support, be it on the level of the industry interested in the crop, the extension services, or the research organizations. Such promotion must continue over a period of several years. We have found that it has been most successful when informational meetings have been held with speakers or comments from industry, from extension, from state or federal research organizations, and from farmers who have been successful in growing the crop.

(8) **Success**: Early success is important in the establishment of a crop. Because a new crop is something of a risk, a farmer will often give it the poorer location on his farm, particularly if the acreage of his main crops is restricted by government allotments. Often in early stages of a crop's development the best area of production is not known, mistakes may occur through ignorance, or unanticipated pests may appear. Usually the average yield is very low. This was true of safflower in 1950 in California, when the average yield was about 600 pounds per acre on 23,000 acres (16). On the basis of that average performance safflower probably should never have been grown again. But some farmers obtained exceptionally high yields. Their experience outweighed the misfortune of all the rest in the future of this crop. If it could be done by one

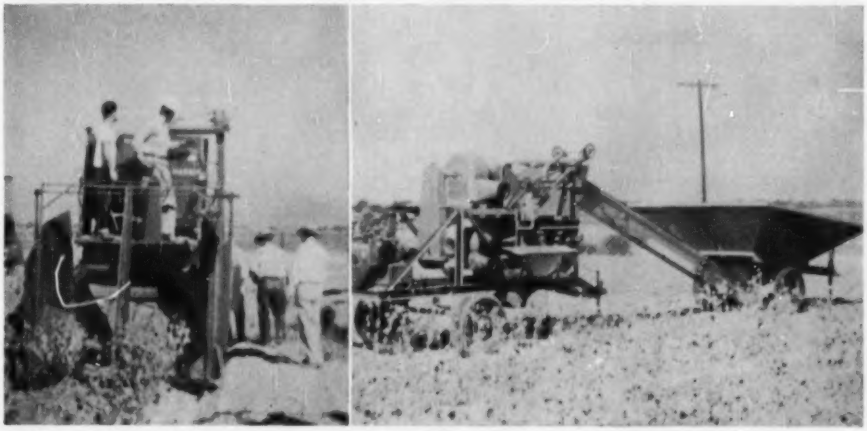

Fig. 1. Castorbean harvester used about 1951. The plants after defoliation with a herbicide were cut with the combine at the left, and the capsules removed. Seeds were taken out of the capsules by a separate machine shown on the right.

person, it could be done by many more. Yields in California now average about 1600 pounds per acre on over 100,000, acres.

(9) **Machinery**: References to machinery have already been made. If specialized machinery is necessary to handle a crop, this places it at a distinct disadvantage. This has been true of both castorbeans and sesame in California. With castorbeans both a harvester and a huller to remove the seeds from the capsules are

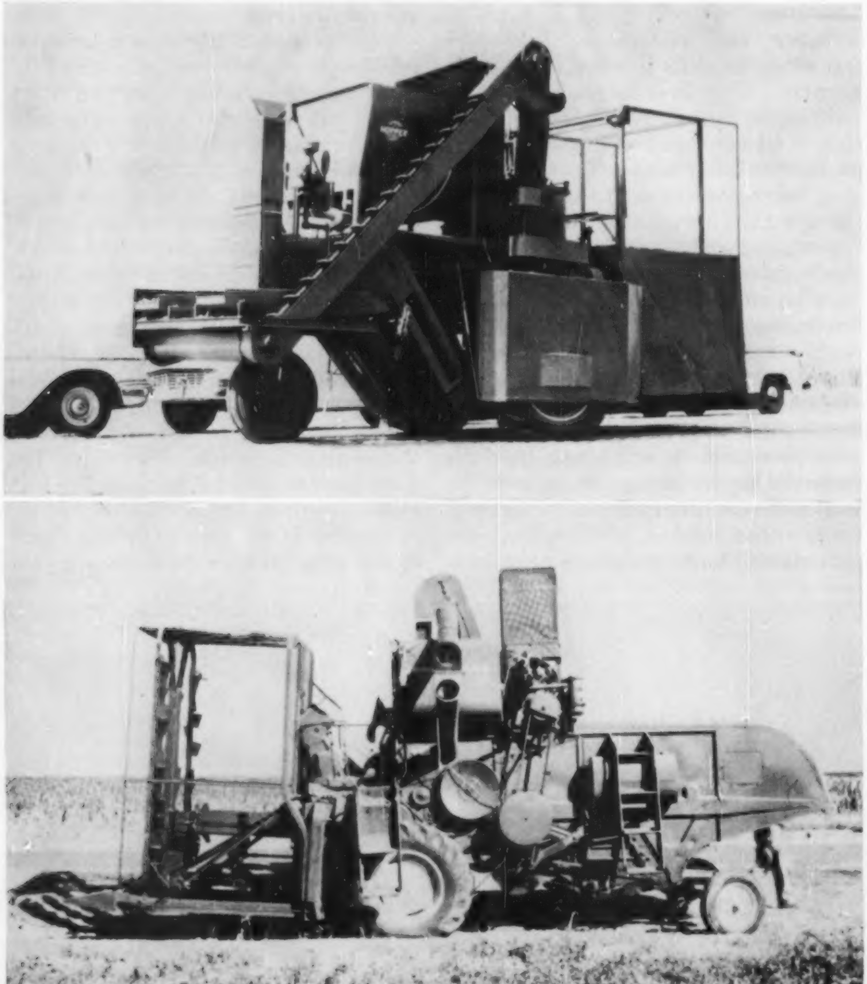

Fig. 2. Modern castorbean harvesters. The upper machine is mounted on a tractor which moves backward through the field. The lower machine is a conventional combine used for small grains, but has a special attachment for the front. Both machines require defoliation of the plants prior to harvest, both strip the capsules off the plant, and both remove the seed from the capsule.

necessary. Thanks to engineers with the USDA and commercial companies (3, 25), great improvements have been made in such machinery and, important also, attachments are being developed that will permit a farmer to use conventional harvest equipment (Fig. 1 and 2). Designs for harvesters for sesame in California have been many and novel (Fig. 3). They range from that laying out paper behind a harvester and placing thereon the harvested plants to a machine developed from a hay chopper.

(10) **Pests:** One advantage that a new crop enjoys in many instances is freedom from pests, particularly pests that have developed and become adapted to the crop in the country of origin. In California, safflower has been relatively free of insect pests, and has suffered severely from only two diseases, rust (*Puccinia carthami*) and root rot caused by *Phytophthora drechsleri* (16, 17). In France, however, where safflower was developing commercially about the same time as in California the larvae of the safflower fly (*Acanthophilus helianthii*) forced the crop out of production by 1953 (16). This pest was present in the wild composites bordering the safflower fields. It was interesting to me to note that sunflowers in Southwest Asia suffered much less from insect damage than in California and other parts of the United States, presumably because the pests of this continent were not there. Castorbeans are severely attacked by rust in Africa, but the disease is not present in the United States. These observations on pests suggest two procedures to those working on new crops. The first is that every care be taken in the introduction of new crops to avoid introducing pests at the same time. The second is that efforts be made to evaluate new crops in the countries where pests are present, to permit the selection and development of resistant types. These procedures, of course, are not peculiar to the new crops. They will apply equally well for most introduced crops, even those of long-standing.

(11) **Crop design and growth pattern.** No mention has yet been made of the new crop itself, its design, dimensions and pattern of development, and the bearing of these on its success. With safflower, its

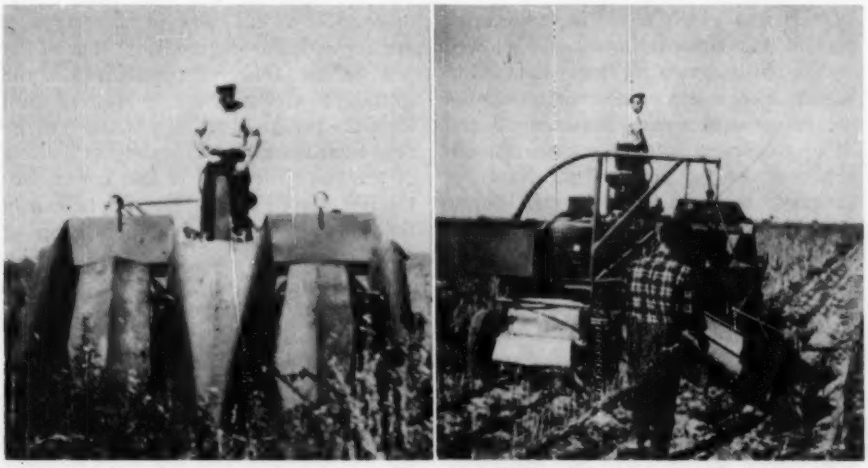

Fig. 3. An experimental sesame harvester used in California. Plants were cut while still rather green, chopped into small pieces, and then placed on paper laid in every fourth furrow. When dry the sesame was picked up and threshed.

slow development and rosette habit of growth in seedling stages has made it a second choice to barley for fall planting in California. Barley grows more rapidly, and is better able to compete with weeds. On the other hand, for spring plantings it has been favored over barley because it will suffer less from high summer temperatures, and barley is particularly susceptible to yellow dwarf, a virus disease, in late plantings. The acreage of safflower has been increased by its ability to forage deeply for moisture, but its deep roots have handicapped it in shallow soils. Its ability to grow without supplemental irrigation water has helped it in many locations in northern California; its susceptibility to root rots under surface irrigation has handicapped it in other areas. Castorbeans are hard to harvest because of their indeterminate habit of growth—the early racemes are ripe long before the later ones, and the plant must be defoliated prior to harvest. Ramie has not been successful as a fiber crop primarily because of difficulty in removing the fiber from the stem.

The nature of the seed is important. Safflower in the decade preceding World War II was widely tested in the western part of the United States, and showed some promise as an oil crop. It failed to become established commercially because the oil content varied between 20 and 25%, too low to attract commercial oilseed processors. Not until the Nebraska varieties, with 30 to 36% oil, became available after the war, did safflower become established commercially.

It is perhaps redundant to point out that the yield of seed is important also. What is considered an adequate yield is, of course, related to the costs of production. Sesame shows promise as an oil crop in Texas with yields rarely reaching above 1,000 pounds. Under irrigation in California, with optimum growing conditions and with very little loss of seed from shattering, it has been difficult to obtain yields above 2,000 pounds per acre. If the limit of sesame yields is no higher than this, I doubt that it will be successful as an oil crop in California except on a very limited scale. Castorbeans, on the other hand, has given maximum yields above 5,000 pounds of beans per acre, or about 2,500 pounds of oil, a performance that cannot be excelled by any annual oil crop in the United States. Unfortunately these evaluations of genetic potential usually come too late, after costly experimentation under field conditions by farmers. This was true of both castorbeans and safflower in Imperial Valley in 1950. Thousands of dollars would have been saved those farmers if they had then the information available now. We need more work of the nature of that done on canaigre (*Rumex hymenosepalus* Torr.), a tannin containing crop not yet under way in the United States (11). For this crop we now know its soil requirements, methods of propagation, rates of planting, and so on. Regrettably, a war is usually necessary to stimulate such investigations.

(12) **Genetic adjustments**: New crops are always handicapped because the original introductions will have been developed under an environment different, to a greater or lesser degree, from that of the new habitat. The full possibilities of the introduced crop will not be realized until its entire genetic variability is tested in the new environment. This highlights the role of the plant breeder. It also emphasizes the importance of spending the necessary time and resources for exploration of genetic potential.

Castorbeans are an excellent example of what can be done through breeding over a period of about 15 years (25). All varieties are now resistant to shattering. A gene for short internodes has been introduced in commercial varieties. This gene has reduced the height of the plant, making it easier to harvest and more resistant to wind damage at harvest time. A recessive gene producing racemes with female

flowers only, has been utilized in the production of hybrid varieties.

The plant breeder may also be able to modify new crops for other uses, not apparent on their first introduction. Safflower earned its reputation as a drying oil. But a recent mutant gene has been reported (13) which will change the iodine value from about 140 to 90, a profound change in the fatty acid composition of an oil (Table II). Though this oil appears to have the characteristics of olive oil, it has not been of much interest to the oilseed industry. But the example does indicate the potent effect of a single gene. Better known, of course, are the mutant genes that have increased the amylose fraction of the starch in the corn kernel (23).

The synthesis of a totally new crop offers even more interesting possibilities to economic botanists. Through gene changes this might be achieved from existing crops or from wild species. More likely, at least over a short period of time, this will be achieved by manipulation of the chromosomes. Along these lines I am intrigued by Jenkins' program of research (personal communication) at the University of Manitoba, in which he is studying the agronomic possibilities of polyploids produced by different combinations of genomes of *Triticum, Agropyron, Secale, Aegilops* and *Haynaldia* species, both as these genomes are found in nature and as they may be modified through various chromosome exchanges. On a much less ambitious scale we are studying the possibilities of different combinations of genomes of safflower species, hoping that some combination may yield something with unusual oil characteristics, unusual agronomic behavior, or unusual resistance to disease (2). The use of induced polyploidy in the improvement of grasses has been described by Love (20).

TABLE II

FATTY ACID COMPOSITION AND IODINE VALUE OF TWO TYPES OF SAFFLOWER OIL, OLIVE OIL, AND PEANUT OIL

Source of oil	Saturated acids	Oleic acid	Linoleic acid	Iodine value
Safflower[1]				
"Normal"	6-10	13-22	72-79	143-148
Low iodine	4-8	74-79	11-19	91-101
Olive[2]	13.9	77.5	8.6	79-90
Peanut[2]	17.1	61.1	21.8	84-102

[1]Horowitz, B., and G. Winter. 1957.
[2]Eckey, E. W. 1954.

(13) **Plant introduction and evaluation:** In providing flexibility to a crop, the plant breeder can be no more successful than the materials he has available. If the variability is great, through selection or recombination of genes, he can develop more suitable types. The importance of plant introductions cannot be over-emphasized in this connection. As an example of the value of introductions, I can refer to safflower. Largely this crop was established on the basis of the performance of introductions (4). N-852 was a direct introduction from the Sudan that was released to American agriculture with only the offtype plants removed. N-10, still in production, was a selection of N-852. N-6, almost disappeared now, was a selection out of an introduction from Egypt.

Dr. R. E. Schultes has pointed out in this Symposium that primitive peoples often lose their knowledge of medicinal properties of plants after closer contacts with the civilized world. In a similar way a modern agriculture, as it influences primitive types, may cause the loss of valuable plant materials. A primitive agriculture maintains a great deal of genetic variability in crop plants, which expresses itself from farm to farm and village to village. These variable forms may be replaced by the improved varieties of a modern agriculture. The improved varieties, however, are usually of one or a limited number of genotypes. It is quite likely, too, that they could be further improved by genes from the primitive varieties that are taken out of production. The solution is obvious: as modern agricul-

tures remove primitive forms it is imperative that some effort be made to preserve the variability in the crops so displaced.

Our concern must range, however, beyond plants already established in agriculture. Jones and Wolff (15) have described in detail the nature of the information that is needed in the evaluation of species of higher plants for their economic potential, so I will not repeat it here. It is encouraging to know that Federal agencies—the New Crops Research Branch and the Utilization Laboratories of the U. S. Department of Agriculture, for example—are cooperating in this endeavor. Certain industries are studying plant species in a similar manner, as the recent paper by Raffauf and Flagler indicates (22).

As a plant breeder interested in the improvement of safflower through the introduction of genes from domestic or wild sources, I am hopeful that the economic taxonomist will also have in mind the following, at least with respect to safflower species: (a) the distance in 10ths of a mile or kilometer from a prominent landmark—I have failed to obtain wild species in North Africa because this was not noted on the labels of herbarium specimens; (b) more collections of mature seed—I realize that this is often difficult; and (c) records of abnormalities. Actually these records of abnormalities may be very valuable in indicating sources of resistance to disease or insects. It was of interest to me to find abnormal heads on a specimen of safflower collected during the middle of the 19th century (Fig. 4) in Afghanistan, in the herbarium of the Royal Botanic Gardens, Kew. This suggested that I be on the look-out for a similar condition when collecting safflower in that country in 1958. A similar condition was indeed found in safflower of the Kabul area, its cause unknown to me, though the condition appeared to be associated with damage to the receptacle by insects.

It is, of course, much more interesting to analyze the data obtained from differ-

Fig. 4. Abnormal safflower from Afghanistan in which the florets of the head grow vegetatively to produce minute secondary heads which are sterile. On the left—about 1/3 actual size—from a herbarium specimen collected about the middle of the 19th century. On the right three heads—about 2/3 actual size—photographed in 1958. From left to right these three heads are normal, the florets partially developed vegetatively, and most florets developed into secondary heads.

ent collections of the same species or different species of the same genus. Such studies indicate the dynamics of species, the probable direction of evolution in the past, the changes that may be taking place now. Wild relatives of many old crops have been investigated in detail, but more work is needed on species closely related to the new crops.

We agronomists, in examining the variability present in our own crops, have often failed to analyze it critically. We are usually satisfied to list the variability of world collections by countries, and forget that countries are often large with many different habitats. Data from collections of safflower in four countries will serve as an example of what might be found in such studies—the data were obtained from materials grown at the USDA Plant Introduction Station at Pullman, Washington, in 1959. With respect to oil content of the seed, (Table III), Iran provided introductions that had the highest oil content on the average and the highest iodine value (Table IV). India, on the other hand, had a large number of types with distinctly low iodine values. But of equal interest is the variability in oil content of collections made in Iran—these include only those where the area of collection is known (Table V). Here the Isfahan area provided a high proportion of types with very high oil. I cannot explain why they should be higher than in other areas, but they do suggest that more extensive collection should be made in this area in the future. More interesting, perhaps, will be the analyses of a closely related wild species of safflower, *C. oxyacantha,* collected from many areas of of Southwest Asia, but this is something for the future.

TABLE III

Oil Contents of Safflower Introductions from Selected Countries Grown at the Plant Introduction Station, Pullman, Washington, in 1959

Country	Oil content in per cent 23.1-25.0	25.1-27.0	27.1-29.0	29.1-31.0	31.1-33.0	33.1-35.0	35.1-37.0
India	4	8	23	73	17		
Iran		8	8	12	6	17	2
Jordan	3	6	1				
Egypt		2	3	26	4		

Frankel (10) has urged an analytical approach to plant introductions. For example, in commenting on the merit of searching the Vavilovian "centers of diversity" he points out that these are centers of qualitative variability, not necessarily centers of the maximum expression of a character in a particular direction. These will be found most likely at the fringe of the distribution of a species where particular environmental stresses may be greater. Hartley and Williams (12) have found that most of the pasture grasses of economic importance developed from types growing in woodlands or forest margins, not as one might expect from types in the steppes, prairies and pampas.

(14) **Individuals**: Too often we ignore the role of the individual in the recogni-

TABLE IV

Iodine Values of Safflower Introductions from Selected Countries Grown at the Plant Introduction Station, Pullman, Washington, in 1959

Country	Iodine value 81-90	91-100	101-110	111-120	121-130	131-135	136-140	141-145
India	2	4	1	3	6	37	69	3
Iran					1		17	35
Jordan						1	7	2
Egypt							22	13

TABLE V

Oil Contents of Safflower Introductions from Different Areas of Iran Grown at the Plant Introduction Station, Pullman, Washington, in 1959[1]

Town	Area	Oil content in per cent 25.1-27.0	27.1-29.0	29.1-31.0	31.1-33.0	33.1-35.0	35.1-37.0
Tabriz	NW	5	1				
Tehran	North Central		1	2		3	
Meshed	NE	2	5	4			
Isfahan	Central			1	4	12	2

[1]These include only the collections made by the author.

tion and establishment of a new crop. Though time prohibits the mention of names here, many of them will be known to you. They occupy all levels of new crop development, from research to promotion. While the contribution of the individual will always be important, and his efforts sometimes critical, more often than not the cooperative effort of several persons will be necessary to establish a new crop. This is particularly true of crops used for industrial purposes where variety improvement, production practices, processing and market developments must be kept in some sort of balance.

Conclusion

To conclude I would like to repeat a few points. New crops have been established in our economy in the past, and will likewise be established in the future. As time progresses, each new introduction will be made with greater difficulty, the chief obstacles being the morphological characteristics and developmental patterns of the species involved. Economically speaking the early developmental stage will be most critical, when the plant product is almost established in the market, when farmers are hesitant to grow it, when industry or governments must give it a helping hand. New crops of greatest interest will be those of potential use to industry, those yielding pharmaceuticals, those to populate range areas, and those involving the lower organisms. In the society of our agricultural crops new crops are the pioneers. Their road will be more difficult than that of the established crops, but more exciting too.

ACKNOWLEDGEMENTS

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Plants as Sources of New Drugs[1]

The search for new drugs from plants poses a number of problems. Collection, identification, selection, and testing of plants, as well as the extraction and isolation of potentially useful constituents are discussed, wih reference to the alkaloids as examples, from the point of view of the industrial research laboratory.

ROBERT F. RAFFAUF[2]

The plant kingdom is the source of a fantastic variety of chemical compounds ranging in complexity from the simple but extremely toxic potassium fluoroacetate found in *Dichapetalum cymosum* of southern Africa to the complicated pyrrole derivatives which we recognize in the chlorophyll pigments of all green plants. The isolation and identification of these components is intimately associated with the very beginnings of organic chemistry and in the past century a large number of them has found use as flavors, drugs, dyes, perfumes, and miscellaneous other products. The economic importance of these compounds is difficult to estimate for, in addition to the useful ones, many plant constituents are toxic to grazing animals and responsible for appreciable economic losses in many areas of the world.

Our heritage of plant drugs from the centuries of the past is too well known to require comment here. I wish, therefore, to confine my remarks to the search for new drugs and some of the problems associated with it, particularly from the standpoint of the industiral laboratory whose approach must be as broad and yet as practical as possible. For, short of a complete chemical investigation of each new plant — an interesting and often profitable exercise — some limits must be placed on any deliberate effort to find useful medicinal agents.

Perhaps the easiest way to define these limits is to search for the answers to a few simple questions: What are we looking for? Where can we expect to find it? How can we identify it? What are the obstacles to obtaining it?

I have already mentioned that we are looking for new, useful drugs — comparable to or better than those which the plant kingdom and chemical synthesis have yielded in the past. Utility is obviously relative to the environment in which it is sought or the individual seeking it. For our present purposes we will recognize it as the production of an observable and reproducible physiological response in experimental animals — and eventually in man — which can be used for the relief or cure of a recognized disease or disorder. Granted a limited medicinal usefulness of the cathartic anthraquinones, the digitalis-like cardiac glycosides, the bioflavonoids, and a few other miscellaneous compounds, the most interesting type of naturally occurring derivatives, from many points of view, is the class of nitrogenous bases known as the alkaloids. These may be simple or complex in structure but as a class they produce a high order of physiological response in animal systems. This is often observed as gross toxicity and death but it is also in this group of compounds that we find many of our well-known drugs.

With a few exceptions, the peoples of the world have developed herbal medicine to a greater or lesser degree. Perhaps the

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[1]First Annual Symposium: Integrated Research in Economic Plants. Purdue University, Lafayette, Indiana, May 21, 22, 1960.

[2]Smith Kline & French Laboratories, Philadelphia 1, Pa.

most extensive of these bodies of folk-lore is that of the Indian systems of medicine which have recently given us reserpine from *Rauvolfia serpentina*. Much of this folk-lore has been compiled and the anthropologists and ethnobotanists continue to add to the fund of knowledge by their studies of relatively little-known cultures. It would seem a simple matter, by reference to this literature, to select any number of plants for detailed investigation which have been "proved" by centuries of human use. This method is not to be overlooked and in specific instances extremely interesting scientific developments have resulted from its use. However, as a general method for selection this must be used with certain reservations. The folk treat symptoms, not disease; indications are vague and dosages approximate; the same plant is often used to treat a variety of apparently unrelated symptoms; a plurality of local names for the same plant or a single name for a number of plants add to the general confusion. In many societies, the treatment of disease is closely associated with ritual, magic, or witchcraft, the plants having some accesory role and no real medicinal use at all. We are thus led to the point of view that an almost routine testing of selected portions of the plant kingdom for alkaloids is a reasonable method for finding new drugs. Such a method will eventually and automatically include the herbs mentioned in the folk-lore.

Such surveys have been made before; the results of testing of parts of the flora of Australia, Borneo, Hawaii, and Malaya appear in the literature and our own Department of Agriculture has published reports covering the screening of ca. 5,000 plants collected on a world-wide basis. Based on these results and on literature reports on the testing of individual plants, Willaman and Schubert, in their paper on "Alkaloid Hunting" in ECONOMIC BOTANY a year or two ago, have been of much assistance to the chemist in directing his search to plant families or genera known to contain alkaloids.

It is unfortunate that not more of these surveys have been published. It would be of help, too, to have some notion of the geographical distribution of alkaloid-containing plants. Is it true, as many have supposed, that tropical species are relatively richer in alkaloids than the temperate ones? We have found alkaloids in a number of temperate genera where their existence was previously unsuspected — in spite of the fact that the plants are otherwise well-known!

This thought introduces another problem: that of the variation in total alkaloid yield and in individual alkaloid composition of plants grown under different ecological conditions. It is not always easy to state, without reservations, that a plant does or does not contain alkaloids. In some families, e.g. Apocynaceae, these substances tend to concentrate in the root or bark often to the exclusion of other parts of the plants, whereas in the Compositae alkaloids, if any, are to be found in or near the flowering tops. In other cases collection in proper season plays a very important role. It becomes necessary for the chemist to make as complete an assay of his plants as possible before reporting his results.

So far we have established that we will find our useful drugs among the alkaloids, that our statistical chances of doing so are better by rountine survey methods, and that in carrying out such a program proper attention must be paid to such things as seasosn, climate, and plant parts to be tested.

There are a number of problems involved in the testing for alkaloids. In our own experience none of the methods which have been used for years is completely satisfactory. Certain types of compounds, e.g. proteins, may give precipitates with the usual alkaloid reagents, leading to false positive results. Others,

e.g. ephedrine, do not give precipitates with some alkaloidal reagents, e.g. Mayer's, and may thus lead to false negative results. Certain non-alkaloidal plant constituents may be "salted out" of acidic aqueous solutions by the heavy-metal reagents leading to a false positive interpretation. These interfering compounds may be removed by prior treatment of the solutions with sodium chloride. On the other hand, some alkaloids, e.g. alstonine, may be quantitatively precipitated as hydrochloride by this method. We have found that many plants contain quaternary alkaloids, often to the exclusion of other bases, which are not extracted from their aqueous solutions by ether or chloroform. These may be missed in some qualitative test procedures as will amine oxides, a naturally occurring form of some alkaloids more widely distributed, according to some reports, than previously suspected.

Thus a test procedure must take all of these factors into account by a combination of methods or reagents. Perhaps the most satisfactory test is a small-scale adaptation of alkaloid extraction and isolation techniques; although it takes somewhat more time, the results give a much better estimate of what can be expected from a particular plant. Unfortunately we do not know of a satisfactory field method for alkaloid testing which would be of immense benefit to the surveyor.

Except in rare instances it is impractical to collect, extract, process and test plant materials containing less than 0.01% alkaloid. The so-called qualitative test should therefore have quantitative implications. At least 20 g. (dry weight), and preferably more than this, of plant sample should be tested so that the precipitates are strong enough to allow semi-quantitative estimation of total alkaloid content. The use of a procedure similar to the expected large-scale processing permits the chemist to anticipate difficulties e.g. intractable emulsions, which might arise later. The importance of testing cannot be over-emphasized; the often long and expensive chain of events involving collection, drying, grinding, extraction and processing of 10-100 Kg. of plant material is predicated upon the result of this simple preliminary step.

If the preliminary testing has been done properly, extraction of plant materials for alkaloids usually poses no problems. Many methods are available and after a bit of experience with pilot runs, one can be chosen best suited to the plant in question. The chemist must guard against the instability of some alkaloids to elevated temperatures and air oxidation, and against the possibility of the production of artifacts during extraction. Some plants e.g. *Saussurea lappa* which contain labile non-basic constituents may yield nitrogenous materials on extraction with ammoniacal solvents; others contain alkaloids susceptible to modification by acidic extraction. The major problem is often acquisition of sufficient supply—25, 50 or 100 Kg.—of plant to yield adequate quantities of alkaloid for pharmacological evaluation.

Isolation of individual constituents from the extract is often quite another matter. Plants containing mixtures of from five to twenty-five closely related bases are not uncommon and in spite of chromatography, counter-current distribution and other modern chemical techniques the oganic chemist is often severely challenged by problems of separation and purification of the components responsible for the activity which the pharmacologist observes.

I have not discussed the problems of isolation of compounds from plants which, like diosgenin, for example, become useful by chemical modification. Obviously supply is also the major problem here. Questions involved in the pharmacological evaluation of new drugs will be covered in another portion of this symposium, but we can recognize here

the chemist's frustrations at having his hard-won compounds fed to animals in a long series of experiments which often involve considerably more interpretation than his own determinations of physical constants, spectra, and molecular structure.

In conclusion I should like to express my personal belief that the key to success in the search for new drugs from plants is the botanist. Without regular collection and identification, surveys of even limited portions of the plant kingdom cannot be effective; without adequate supplies — and it may take as much as 100 Kg. of dried material to yield enough alkaloid for one series of definitive pharmacological experiments—it becomes impossible to evaluate the medical usefulness of newly discovered plant constituents. We hope to avoid some of the confusion that has occurred in the literature by having prepared and deposited in a recognized herbarium a specimen of each plant on which extensive chemical work or pharmacological testing is undertaken. We will supply the best methods we can devise, but we rely on the botanist to supply us with the materials with which to work, and as long as he is willing to cooperate we can proceed in the conviction that the plant kingdom will yield many more interesting substances of eventual use to mankind.

Peppermint and Spearmint Production[1]

N. K. ELLIS[2]

The history of the production of peppermint in the United States reads like an abridged version of the rise and fall of a series of civilizations. This plant or forms of this plant have been used for many hundreds of years. Japanese medical books report the use of peppermint oil in an eye wash. Distillation of the oil from the plant was reported as early as 410 A. D. by the Egyptians. Undoubtedly distillation was known long before that.

The present peppermint plant, *Mentha piperita* L., existed in its present form at least in 1696, for it was described at that time by John Ray in England.

As the uses for peppermint became more numerous, the production increased and in recent years there has never been a short crop except that caused by adverse weather during 1925-26.

We must assume that the mint flavor became popular slowly at first and then rapidly in recent years for it is said that distillation of the herb to obtain the oil prospered in England; by 1796 there were at least 100 acres planted to peppermint near Mitchum or in County Surrey, England. The world's supply and demand was probably between 2,000 and 3,000 pounds of oil. By 1844 it was reported that the world production was approximately 12,000 pounds of oil. One hundred years later, in 1940, the production was 867,000 pounds, and last year, 19 years later, we produced 2,388,000 pounds.

Piecing together the history of the production areas of this crop, it is thought that stolons of the plant were first imported from England about 1812 and that the first plantings were made in the vicinity of Ashfield, Massachusetts. About 1816 some growers from the Ashfield area moved to New York and established an industry there. Wayne County, New York soon became the leading oil producing center in the country, but within a short time competition developed from "the West," for "roots" had been taken to Ohio. About 1835 peppermint plants were introduced into Michigan in St. Joseph County on the Indiana-Michigan border. The muck lands of southern Michigan and northern Indiana proved so well adapted to mint culture that the center of the industry soon became located here. But again the production did not remain localized, for it spread out from this original center into more northern organic soil areas of Michigan and the three northern tiers of counties in Indiana.

While Michigan and Indiana were riding high as the world's production center of peppermint, competition in the far west began to develop, when small plantings of mint were established in Oregon in 1919. These later spread to Washington. Today, the major production areas of the United States, and even of the world, are to be found in the Columbia River basin, east of the mountains in Washington, and in the Willamette Valley in Oregon.

The history of the spearmint crop is less well documented, for its popularity in the form of oil seems to be of more recent time. We will see, however, that the spearmint follows the peppermint, for it has one important advantage in that it is less susceptible to the *Verticillium* wilt which attacks peppermint and can therefore be grown on soil that will no longer produce the peppermint crop.

In the late 1940's, production began to

[1]Presented at First Annual Symposium of The Society for Economic Botany; *Integrated Research in Economic Plants.* Purdue University, Lafayette, Ind., May 22, 1960.

[2]Agricultural Experiment Station, Purdue University, Lafayette, Indiana.

be developed in Wisconsin. Wisconsin had always had the potential for producing oil, but growers had not become particularly interested. Perhaps one reason was that the conservationists in the state of Wisconsin discouraged drainage of the organic soil, and so local producers did not become interested. However, in the forties, growers from Michigan and from Indiana bought land in Wisconsin to begin production of the crop. An interesting sideline to this is that one of the outstanding essential oil chemists, Dr. Kremers of the University of Wisconsin, pointed out the potential in the production of this crop in the early years of this century, but could not encourage production of the oil.

The USDA publishes the current distribution of acreage in the five principal producing states for peppermint as well as spearmint. So in this rise and fall of production areas, first Massachusetts, then New York, then Ohio, and California have disappeared from the records, and proud Indiana which once boasted 40,000 acres of peppermint now has only 4,700.

Before discussing production and some of the factors which influenced production of mint oil, we should take a quick look at the origin of the plant. There are many species of mint and as many selections of *Mentha spicata* exist as there are natural crosses. This is a fertile plant and the commercial selections of spearmint have been selected chiefly by the growers for quality and high oil production.

The peppermint plant is somewhat different. It seldom sets seed, and therefore *Mentha piperita* L. var. *vulgare,* or as Nelson wishes to identify it, *Mentha piperita* L. 'Mitchum,' is thought to be a naturally occurring hybrid. It has been postulated that the parents were *Mentha spicata* L. and *Mentha aquatica* L. It is further postulated that *Mentha spicata* is itself a cross between *Mentha sylvestris* L. and *Mentha rotundifolia* L. This would indicate therefore that *M. piperita* is really a three way cross involving *M. aquatica, M. sylvestris,* and *M. rotundifolia.* I might say, however, that although considerable work has been done in breeding for mint resistant to the current diseases, geneticists have not been able to reconstruct this cross and come up with the quality oil which comes from this naturally-occurring hybrid.

We used to speak of other strains of peppermint being grown as white mint and American mint, but these are not strains that are in commercial production. Although there are some variations in the planting stock of the different growers, all of the present production of black or black Mitchum mint is essentially quite similar. The record shows that there is quite a bit of difference between the price of oil on the west coast and that in the midwest although the same planting stock is used for both areas. There is a distinct difference in the quality of the oil and consumers have been willing to pay more for midwestern-produced oil than for that grown in the west. The midwestern oil can be used with only redistillation while the western oil must be fractionated to take out certain unfavorable flavors and aromas.

There is some production of oil from *Mentha piperita* in other parts of the world. There is small acreage in Italy, perhaps some in France, and a few, perhaps a 100, acres still remaining in England. Brazil now produces some peppermint oil, and, prior to the war, Russia was a large producer of this crop. Our neighbor to the north, Canada, has attempted to get into production on several occasions. There is a large organic soil area just north of New York state, and in Ontario, opposite the Detroit area, a planting was made.

In addition to flavoring, it is well known that much menthol is used commercially in this country. Menthol does not come from the peppermint plant, *Mentha*

piperita, but has in the past been produced from the so-called Japanese mint, *Mentha arvensis* L. var. *piperascens*. This mint oil may contain as much as 75 or 80% of free menthol and the menthol is easily crystallized out. Prior to World War II practically all of our menthol was coming in from Japan. The Japanese colony that developed in Brazil also produced this type of peppermint, and some production of *Mentha arvensis* was to be found in California. This plant will grow here, but the value of the oil is far less than that of the regular peppermint. Our best yield, when we were tempted to produce it, was about 35 pounds per acre.

FACTORS INFLUENCING PEPPERMINT OIL PRODUCTION

Soils

The mints actually grow on a variety of soils but they have done very well on the organic soils in the midwest which retain large amounts of moisture. This is probably the main reason for the success of this crop because it is not necessary that it be grown on muck or peat. This is obvious from the fact that major production on the west coast now is on mineral soil. The soil reaction has not seemed critical. The peat soils of northern Indiana and Michigan range from as low as pH 5 to soils which are neutral or even alkaline at pH 7.5, and there is no great variation in production unless the soil becomes exceedingly alkaline.

The soils of the west coast are silt loam in the Willamette River Valley and require overhead irrigation throughout the growing season. In the Columbia River Valley, the soils are alkaline, volcanic ash in origin, and a large part of the area is irrigated by furrow irrigation although some sprinkler irrigation is also used. In the areas that are furrow-irrigated, some growers have indicated that they must have at least 60 inches of irrigation water per year available to be sure of a profitable crop. Irrigation has not been profitable in the midwest except in establishing the crop to assure a good stand.

Propagation of Mint Crops

Both spearmint and peppermint are propagated vegetatively using the stolons or young plants obtained in the spring from established plantings. The stolons (which the growers usually call roots) are lifted by potato diggers or plows, shaken to free them from excess soil, and planted in rows. The first year planting is called "row mint" because it is retained and cultivated in the row. Crops planted from stolons are expected to produce an excellent crop the first year. If planting stock is short the acreage can be expanded by using "plants." These "plants" are set with a transplanter similar to that used for the transplanting of celery. However, in the case of peppermint, yield is not expected to be as good from fields planted with "plants" as from those planted with stolons, but with spearmint the yield is often exceptionally good when the crop has been planted from "plants" in the spring.

One acre of good mint on organic soil should produce enough stolons to provide for 10 to 15 acres of new planting. On mineral soil one acre seems to produce planting stock for only three to five acres of new planting. As we will see later, day length is very important to the peppermint crop. In relation to planting stock we find that stolons will be produced only under short day conditions, and in the spring as the plant begins to grow, plants and roots are sent out from the nodes of these stolons so there is a very limited time between the thawing of the soil and the beginning of growth when the stolons can be used for planting stock.

I have mentioned that the mint is grown in rows the first year. After harvest and just before frost, this mint is plowed down. Plowing does several things in the midwest. It protects the crop from winter killing during the coming winter, thins

out the stand somewhat, and distributes the stolons completely over the soil so that in the second year the field is completely covered with mint stolons. By clean plowing at least one disease is retarded. The term used for the second year crop is "meadow mint."

In the Willamette Valley, at least where the mint is grown on mineral soil, the fields are subject to flooding during the winter and so the growers do not plow down their mint until spring. If a deposit of silt is laid down by the river during the winter, the silt is turned under at the time the mint is plowed in the spring and prior to working of the soil.

Soil Fertilization

In spite of the fact that workers have studied the fertilization of the mint crop for a number of years, the production of oil is such an elusive thing that it would be a brave individual who would claim to know how to fertilize the soil for mint production. Organic soils are normally low in potassium, therefore potassium must be added. Since most of the minor elements exist in sufficient quantities, there is little need for further addition. However, reports that copper, zinc, manganese, and sulphur will improve mint growth have been made. Phosphorus has been associated with oil production, and Dr. F. C. Steward, among others, has extensively studied the nitrogen metabolism of the mint plant. The few conclusions that can be drawn are 1) within limits there is no relation between total growth of hay and the yield of oil, 2) no one element is extremely specific for increasing the production of oil, 3) the production of oil is far more elusive than production of a grain or total dry matter, but we do now have some gross guide lines to go by which were not available to us even twenty years ago. Before I go into these we should discuss harvesting of this crop.

Harvesting

Empirical methods have been used for determining when to harvest a crop. About 1941 we here at Purdue determined that the amount of free menthol in the mint oil was a good gauge of the optimum time to cut. A viscosimetric method was developed for determining the quantity of free menthol in the mint. It appears from data published by St. John and Watson some 16 or 17 years later that this method might be applied by recalibration to west coast oil, too.

Basically, harvesting hinges around maturity of the crop which means time of flowering in some areas, but in some seasons under midwest conditions, very little flower develops. So this criterion is useless.

When the grower decides to cut the mint, it is cut with a mowing machine and allowed to dry in the field until the moisture content has been reduced to approximately 35%. It is then carried to the mint still where it is treated by a simple steam distillation process. Many growers have now devised field distilling tubs. These tubs are loaded directly in the field, hauled to the steam supply and condenser, and distilled right in the same tub. This eliminates much hand labor, and often speeds up the distilling process. The distillation process usually takes about 45 minutes. When the herb or mint hay is spent of oil, the hay is hauled out and either spread out on a field immediately or stacked so that it will rot before it is spread on the land. Before the use of insecticides, and when there were more cattle on the farms than there are now, the so-called mint hay was fed to cattle. Sheep and horses did not seem to object to this hay. With the disappearance of horses from most of the muck farms, the hay began to be used for adding organic matter back to the soil.

Following are some of the factors that affect oil yield. I do not presume that these are complete, for a large volume of literature has been developed within the last 20 years on this subject.

Day Length

The peppermint plant in particular requires a long day. It has been established through laboratory experiments that little oil will be produced in a 14 hour day length, and for economical production, the day length must approach 16 hours. This is one of the major explanations for the high oil yields obtained on the west coast as compared to those obtained here in the midwest. Since we grow mint in Indiana at 41 to 44 degrees north latitude, our day lengths are 15 hours on the longest day while in the state of Washington, mint is grown from 42 to 49 degrees latitude and the day length may be 16 hours or longer. This, of course, is not the whole story for the atlas indicates that the Indiana-Michigan area can expect 10½ hours of sunlight during the best days of our summer while Washington state may expect up to 12 hours of sunlight. This is still not the whole story, for there is a great difference in the intensity of sunlight between the two areas with the midwest running from 450 to 550 langley units (gn. cal./cm.^{2} on horizontal surface) in Indiana, while eastern Washington may get as much as 700 langley units. Steward and his students have studied the metabolism of nitrogen under long and short days and report that the leaves and stems store soluble nitrogen under short day conditions in excess of that stored by those grown under long days. They have characterized the nitrogens under long and short days by means of chromatography and concluded that soluble nitrogen under long day conditions is dominated by glutamic acid, aspartic acid, and glutamine, while under short day conditions the nitrogen is dominated by gamma amino-butyric acid, glutamine, and alanine. This is a beautiful piece of work, which may be of importance in the eventual identification of the origin of the oil.

Moisture Level

The moisture level at which the crop is grown is another important factor. Experiments were done in the field on controlled water levels. Water levels were held at 16, 27 and 38 inches. Yield of oil increased from 26 to 45 and 47 pounds to the acre on meadow mint while on row mint the yield increased from 11 to 45 to 53 pounds per acre as the water table was reduced. By lowering the water table, more oxygen is admitted to the soil and with oxidation of the soil more nitrogen is released. This is an over simplification, of course because the lack of aeration and low yield of oil and hay can be somewhat offset by applications of nitrogen.

The peppermint plant shows clear symptoms of deficiency for the major mineral fertilizing elements, nitrogen, phosphorus, and potassium. The typical nitrogen deficiency symptom is a yellowish leaf, loss of chlorophyll, and dropping of the lower leaves. The typical symptom for potassium deficiency is marginal firing or yellowing of all leaves, but more seriously affecting the lower leaves. Mint gives the typical phosphorus deficient reaction with both leaves and stems turning purple.

Diseases

As with most other crop plants disease has an important affect on production. I will mention two of the diseases; either may have been the reason for the movement of the mint producing areas from east to west. The first is the one which the farmers call "leopard's spot." It is caused by *Phaceloma mentha,* the mint anthracnose. It causes grey lesions on the stems and the leaves drop off. This disease was very serious in Indiana when I first looked at the mint fields in 1935. We discovered that this was a rather easy disease to control by use of a specific copper fungicide. Better yet, clean cultivation, that is clean plowing in the fall so that no trash remains above ground, will keep this disease well under control.

The second disease is more stubborn. This is Verticillium wilt. This disease is

caused by *Verticillium alboatrum* although prior to 1960 it was not possible to demonstrate that the strain attacking peppermint cannot be transmitted to other plants susceptible to *Verticillium alboatrum*. No soil or spray treatment has yet been devised, but partial control has been accomplished by what I chose to term "soil inversion."

Soil inversion is accomplished by a 36-inch moldboard plow to which is attached an 18-inch bottom which shoves the top layer of soil into the bottom of the trench which is turned by the large moldboard. This buries the section of soil normally the plow section or top 12 inches, at the bottom of a 30 inch furrow, while it brings up the soil that was down 24 to 30 inches to the top. The story of how this technique began is interesting, starting out with actual inversion of the soil with a shovel by the author in 1950. At the Purdue Muck Crop Experiment Farm, we tried to use two plows at different depths without much success. Martin Blad, a grower from South Bend, purchased a 36 inch bottom plow and mounted the pusher type plow on the beam. This was the beginning of the commercial application. Dr. Ralph Green of the Department of Botany and Plant Pathology at Purdue has continued this work and his results are outstanding and most convincing. The 1956 and 1957 results of the experiment at the Northern Indiana Muck Farm are published in Phytopathology, Volume 48 for October 1958, but later results are even more astounding. Comparing conventional plowing with inverted soil, the percent of infection in 1956 was 57% for the conventionally-plowed top soil and 4% for that which had been inverted. After carrying on this study for four years, the percent of infection on the conventionally plowed soils was 74% after four years and 20% for plants in the soil that had been inverted. The yield of oil at the fourth year showed approximately 18 pounds of oil from mint grown on the conventionally prepared soil and 48 pounds of oil from mint grown on the soil that had been inverted.

In years past we have sent planting stock to all sections of the country and at one time used to worry that we would have competition from the south, for plants were sent to Texas, Arizona, Alabama, and Florida, but this is no longer a fear. Here at Lafayette, we are at the lower margin of day length necessary for economical production of oil.

SUMMARY

A prescription for the production of peppermint based on the known data would be as follows. Mint requires a normally fertile soil with high water holding capacity or irrigation available if rainfall is not sufficient. It requires an area having a day length of 15 to 16 hours, as much sunlight as possible, clean planting stock, and disease control measures which have not yet been fully developed.

Plant Tissue Cultures, A Possible Source of Plant Constituents[1]

RICHARD M. KLEIN[2]

A sufficiently large array of plant tissues and organs have been successfully grown in vitro so that there is little theoretical question that virtually any tissue can be so cultivated (2). To date, investigations have been directed towards problems in pure research. A few laboratories have used plant tissue cultures to evaluate antibiotics, plant growth regulants (8), metabolic inhibitors (6), and weed killers, but most of this information has not been published. Nevertheless, the data currently available, when results from many laboratories are correlated, strongly indicate that plant tissue cultures can and eventually will occupy a place in industry comparable to that of fungi and bacteria.

Even a casual examination of the literature indicates some of the problems with which processor of botanicals are confronted. Quality of the raw material, uniformity within and among lots, damage in shipment and in storage, and dependence on weather, revolution, and foreign competition are just a few of the difficulties which tend to increase geometrically with time. When one also considers the newly discovered drugs and industrial chemicals isolated from plant materials, the problems become even more immediate. Finally, as our population expands, the need for ever increasing supplies is magnified.

At the outset, it is necessary to indicate that the practical use of tissue cultures in industry is highly speculative and that this new "tool" is a long way from being ready for use. Relatively few tissue cultures of potential economic importance have been examined; the techniques are still undeveloped, and the economics are far from worked out. At best, there will be a long period of research and development. Nevertheless, the topic has exciting economic and scientific prospects, and an adequately financed and vigorously pursued program on the use of plant tissue cultures should be carefully evaluated. It is instructive to examine some of the methods, problems, and results of growing large amounts of plant material in vitro.

1. Initiation of cultures.—Etiologically, there are four important categories of tissue cultures (3). *Callus tissues,* frequently (and incorrectly) called normal, are derived from the wound tissue initiated at cut surfaces and almost invariably have an absolute requirement for an auxin. *Habituated tissues* are probably somatic mutations of callus and can grow without an auxin, but they are usually stimulated by auxins. *Crown-gall tumor tissues* are induced by *Agrobacterium tumefaciens* and are usually prototrophic for auxin. *Virus tumor tissues* are derived from the neoplastic growth caused by systemic infection of the host plant by an insect-vectored virus. Any of these tissues may have additional nutritive requirements for amino acids, kinins, or vitamins, but as a rule the tumor tissues are the least fastidious and the most rapidly growing. Briefly, the appropriate organ is excised, sterilized chemically or physically, and the desired tissues are planted on one of several media. Tissues from

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[2]The New York Botanical Garden, Bronx Park, N. Y. Preparation of the manuscript aided by a grant (G-8734) from the National Science Foundation.

leaves, stems, roots, or embryos have all been successfully cultivated.

2. Uniformity of culture.—Through the work of Muir et al. (5) and of Bergmann (1), it is now possible to isolate a single cell and to develop a clone of cells from it in exactly the same way as for bacteria.

3. Media.—Several liquid and solidified media have been developed for plant cells. They are formulated from a relatively few inorganic salts, a carbon source (usually sucrose) and where appropriate, an auxin (usually 2, 4-dichlorophenoxyacetic acid or naphthaleneacetic acid). One major economic problem to be overcome is the apparent requirement by many tissue cultures for the relatively expensive coconut milk now being routinely added as a source of yet unknown growth factors. Tulecke and Nickell (9) found that some tissues could use cheaper and more available supplements including yeast extract and bone meal. It is probable that the active substances in coconut milk will soon be characterized with attendant reduction in product costs, and the use of the coconut milk now discarded during the processing of copra would initiate a valuable by-product industry.

4. Culture methods.—The most advanced technique for batch production of plant cells is that of Tulecke and Nickell (9) who pioneered in this field. They found that a relatively simple carboy technique with ten or more liters of media gave excellent preliminary results and have suggested several modifications in their basic design which should permit even better growth. Clearly, these methods are still in the development stage and more sophisticated and efficient machines, such as a modified chemostat, can be expected.

5. Yields.—It is, of course, pertinent to ask about yields. The most rapidly growing of the cultures used by Tulecke and Nickell gave up to 5.7 pounds of tissue in a four week growth period. It must be remembered, however, that these cultures are not to be equated with plant parts in which living cells make up only a small fraction of the total weight. In addition, when heavy inocula are used and temperature, aeration, and the composition of the medium are carefully regulated, higher yields can be expected. The recent discovery that chelation of the trace elements and buffering of the medium increased growth by over 500 per cent (4) suggest that even simple modifications of current procedures may pay off in more efficient production. Chelation may also reduce the requirements for supplements like coconut milk, thus further reducing costs.

6. Other parameters. — Problems in media homeostasis, the maintenance of sterility (antibiotics may be useful here) (9), and the analysis of the relation between synthetic capacity and growth rates do exist. Recent developments in storage techniques for stock cultures, the induction and detection of mutations and continuous flow systems augur well for the future.

Let us examine some of the products which might be produced in vitro. The plants forming medically-important alkaloids, opium and its derivatives, atropine, etc., are not grown here because of restrictive legislation, security problems, and the need for extensive hand labor. In the case of atropine, West and Mika (11) found that a callus culture isolated from the roots of *Atropa* does, in fact, form atropine in economically-feasible quantities. Production was, as might be expected, increased by supplying intermediates. Mika (unqublished) found that crown-gall tumors on *Datura stramonium* contained almost 500% more hyoscine than the roots and up to 300% more tropane alkaloid than the entire plant. These tumors, or root tumors of *Datura*, can be cultured in vitro.

Other compounds are obtained from plants whose growing range is restricted. Stevioside, a sugar substitute which

might have a market advantage over saccharine, is isolated from a plant which grows only in a small area in Argentina. The use of natural products to supplant dyes and intermediates suspected of carcinogenic activity is currently limited by this same factor and such a list can be enlarged at will.

The current interest in the botanicals used by preliterate tribes as "folk medicines" has resulted in the development of tranquilizers, curare, anti-conception drugs, digitalis, and a host of other products which have transformed modern medicine. The public press has reported the activities of missionaries, medical researchers, and botanists who are now looking anew for folk medicine in Africa, Asia, and tropical America. There will be additional problems of import and production as these drugs are developed.

The rapid advance of the medical sciences relating to hormone therapy, have increased the necessity for making available adequate supplies of cortisone, sex hormones, and other steroid compounds. Precursors of the steroids are, of course, present in plants. The steroidal sapogenin hecogenin is a cortisone precursor isolated from *Agave*. The use of *Dioscorea* as an intermediate in steroid synthesis is also well known. Both can be grown in vitro (9, 10) and sapogenins are produced.

In a very comprehensive review, Nickell (7) has shown that leaves, stems, and roots of a huge number of vascular plants contain antibiotic substances active against bacteria, fungi, mycobacteria, protozoans, and viruses. Although streptomycin and isoniazide is currently the treatment of choice for tuberculosis, there has been sufficient research to show that several plants contain potentially useful antibiotics against TB. The possible use of antibiotics from higher plants against the now recalcitrant systemic mycotic infections and virus diseases is distinctly worthwhile and, here too, the use of tissue cultures of the producing plants is indicated.

There is still another advantage of biosynthesis *in vitro*. The chemical composition of many plant-produced drugs is somewhat variable in that complex mixtures of closely related compounds are formed. The curare poisons contain at least twenty alkaloids, sapogenins are frequently mixed, and the composition of natural dyes is still something of a mystery. Not all of the components are active or useful, and it is theoretically possible by appropriate control of precursors and other conditions of growth to force synthesis in a given direction or, equally important, to cause the synthesis of modified molecules whose potency or utility is enhanced. That such an idea is not completely outrageous is seen in the field of antibiotic synthesis.

This discusion can best be concluded by quoting from the paper by Tulecke and Nickell (9) ". . . it is now possible to think in terms of a chemostatic culture of higher plant cells. . . . It is our feeling that these techniques will be useful for studies of basic cell functions, the role of precursors in particular synthetic pathways . . . and the production of known desirable compounds. In essence, these cell cultures represent a new class of mic-
cell cultures represent a new class of mi-croorganisms . . . subject to the regulation

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Chicha[1] Maize Types and Chicha Manufacture in Peru

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INTRODUCTION

The importance of maize in the indigenous civilizations of Peru is attested for by innumerable archeological and historical records, and by the important place that maize has to this day in the economy and lives of the Indian population of the country (8, 9, 13, 17). Similar "maize cultures" existed in other regions of the continent. Maize in these regions had a profound religious and magical significance, as well as great economic importance. This relationship was expressed in many forms, but the chief of these was, undoubtedly, in the drinking of chicha (19, 20). In all the primitive fertility rites of the Indians, chicha always played a predominant role. As Otero (15) has written: "La chicha era el vehículo que unía a los hombres y a los dioses, a través de la fecundidad de la tierra."[3]

There are many descriptions of the use of chicha as means of intercession with the gods (12). If the onset of the rainy season was delayed, elaborate rituals were practiced to induce the Thunder God to send rain: "The people dressed in mourning and marched weeping through the town. They tied up black llamas and dogs so that these would cry from hunger and thirst, and sprinkled chicha beer around them, hoping thus to appeal to the sympathies of the deities."[4]

Garcilaso de la Vega (7), in describing the solemn ceremonies of the first day of Inti-Raymi (The Sun and Harvest Festival held in June), reports how the Inca would drink chicha from a gold cup in the presence of the people as soon as the sun appeared in the east. "Presently the King rose to his feet, the rest being still prostrate, and took two great cups of gold, called *aquilla,* full of the beverage that they drink. He performed this ceremony as the first-born, in the name of his father the Sun, and, with the cup in his right hand, invited all his relations to drink. . . Having given the invitation to drink, the Inca emptied the vase in his right hand, which was dedicated to the Sun, into a jar of gold, whence the liquor flowed down a stone conduit of very beautiful masonry from the great square to the temple of the Sun, thus being looked upon as drunk by the diety."

Many superstitions associated with chicha are still found in some regions of Peru. Perhaps the most striking of these are, as in antiquity, the rituals which link chicha and the soil. Great care is taken, for instance, not to spill a single drop of chicha when it is being drunk in company (8). If some is spilt by accident, it is said that it happened because "the earth is thirsty." In some areas a few drops of chicha are still sprinkled on the land at planting time, always by young girls.

The word chicha is mainly applied in Peru to fermented maize chicha. However, some unfermented beverages made of maize and other products are also called chicha. In some areas, fermented chicha from plants other than maize is also made. In the eastern lowlands, for instance, several fruits, yuca (Manihot), and other plants are used; and in the Pa-

[1]Maize beer. The word is discussed in the text.

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[3]Free translation: "Chicha was the vehicle that linked man to his gods through the fecundity of the earth."

[4]Acosta (1), translated by Mason (11).

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cific lowlands some chicha is also made from *algarrobo* or mesquite (*Prosopis*). The making of chicha in the highlands from quinoa (*Chenopodium quinoa*), oca (*Oxalis tuberosa*) and molle (*Schinus molle*) is no longer common. Chicha from wild plants is now almost exclusively confined to the eastern lowlands of Peru.

The origin of the word chicha is not clear, but it appears to be of Caribbean (Arawak) origin, as a derivation from chichal or chichiatl. In the latter case, the two voices, chichilia and atl mean "to ferment" and "water" respectively; while in the former case chi means "with" and chal means "saliva," and, together, "to spit" or "spit." The word, therefore, describes the principal way in which chicha was made in the past, using saliva to convert starches to sugars to facilitate fermentation and increase the alcoholic content. The usual practice was to chew the maize flour, a task that was usually done by women. In the Peruvian highlands the Quechua word for chicha is akka or acca. In Aymara it is kufa. In Quechua chewed flour is muko, and the chewers of the flour, muccupuccuk. But the practice of chewing maize flour is quite rare today in the highlands and completely absent in the Pacific lowlands. Chicha is made directly from germinated maize flour (huiñpo or jora) (4, 17). The manufacture of both jora and chicha consists of a complex series of steps, of which one of the most important is the choice of the maize type used.

However, very little appears to be known about the technology of several primitive manufacturing processes using maize. Sauer in 1948 (19) stated that the "distribution of sprouting and roasting, of chewing the grain, and of the fermentation (roasted and unroasted?) meal needs further study, as does the occurrence of wine from greenstalks." Some of the main features of chicha manufacture in three different regions of Peru are therefore described in this paper, and also the main types of maize used. The relationships between the two appear, however, to be in even greater need of investigation than the manufacturing technology itself. It is possible that the selection of maize types, specifically for chicha, may have been one of the important criteria used in antiquity in producing some of the many maize types of Peru. This account deals with the following three chicha producing regions: the northern coastal lowlands (Departments of Piura, Lambayeque and La Libertad), and the two Southern highland regions of Arequipa and Cuzco (14). These are also three of the most important maize growing regions of Peru.

MAIZE TYPES

1. Northern Coastal Region

The Northern coastal region from Tumbes south to Casma grows the Alazan and Viru groups of maize types.[1] This region coincides closely to that where the Chimu culture developed in approximately A.D. 1000-1500. The most common maize types within this group are Alazan proper, Aleli, Colorado, Amarillo, and Motupeño. Mixtures with a yellow type from the lower Pacific slopes of the Andes (Maiz Serrano) grown in the region of Huancabamba-Ayabaca are common. There is also some mixture in the Pacasmayo area with a strictly local variety called Pagadroga or Pogaladroga. This variety is extraordinary in being very similar to the long-eared flexible types from the eastern lowlands of Peru (Yurimaguas, Chachapoyas), which are undoubtedly Race Coroico (5). The Alazan group is early maturing and highly drought resistant. The ear is of medium size with about 14-16 rows. Anthocyanin coloration is usually present, being very marked in some plants on the stem, leaves, and husks. The color of the kernel ranges from light to dark red. The Virú group

[1]Collections of maize ears of all the types mentioned in this paper are kept at the Missouri Botanical Garden, St. Louis.

includes the only yellow type (Amarillo), is less drought resistant, and slightly longer maturing than Alazan. Both groups are dented and soft, and are used almost entirely for chicha.

The centers of Alazan cultivation are the valleys of Piura, Chira, Motupe and Lambayeque. The Virú group is grown further south in the coastal valleys of the La Libertad Department, especially in the Virú Valley itself. Chicha is consumed in very large quantities in the whole of this region, but one of the areas of greatest consumption, where superior quality jora and Chicha are also found, is centered in the village of Catacaos in the Piura Valley. The section of the valley where Catacaos is situated is now a cotton producing area where very small quantities of maize are grown. The maize used for chicha manufacture in the village comes from the whole region, but mainly from the upper Piura and Chira Valleys. Some chicha is taken from Catacaos to neighboring towns and villages. But in the main, the reputation of the "chicheras" (the women who make the chicha) of Catacaos is so high that chicha drinkers come from many miles around, attracted by the Sunday market and the many chicherías. There are several important subsidiary centers of chicha manufacture and consumption in the region, of which Motupe is one of the best known.

2. Arequipa Region

In the preparation of huiñapo (the jora of the lowlands) the only maize types used are the purple-black Negro types of Arequipa. Maiz Negro is, however, a completely different type from the purple-black Maize Morado, though the ears of both types are at first sight similar in appearance. Morado is a dye type grown throughout the highlands, chiefly for chicha morada, a non-alcoholic sweet drink popular in many parts of Peru. The chicha is made by boiling kernels and cobs of Maiz Morado with various fruits including quince, pineapple skin, cloves, and cinnamon. After the proper amount of boiling, the liquid is left to cool and sugar and lemon juice are added. The ears of Maiz Morado are small, and the maize is always sold on the ear. Row number is 10-12, but there is much "multiplication." The kernels are very easily detachable from the cob. The endosperm is white, but the alerone is rust red. Maiz Morado is grown at 4 to 6,000 ft. in the warmer, more sheltered valleys. Maiz Negro, on the other hand, is grown at 8,500 ft. in the Arequipa region and also in Ayacucho. This type has a long growing season (8-9 months), while Morado matures quickly (5-6 months), and is grown in very small quantities. The two types also differ in the height of the plant (Negro is much taller) and the intensity of anthocyanin pigmentation on leaves and stems (extremely marked in Morado). Maiz Negro approaches the general Cuzco type in appearance with large ears and about 10 rows of kernels. The Maiz Blanco of Arequipa belongs to the same group since it differs from Negro only in kernel color. Some Cuzco types, especially Cuzco Blanco, are also grown in Arequipa. As with Alazan, the Negro of Arequipa is reputed to produce excellent quality chicha.

3. The Cuzco Region

The maize types used for good quality chicha in the Cuzco region are also quite distinct, but chicha is made from poor grade maize of almost any type, especially Amarillo. The situation in Cuzco is, therefore, extremely complex, especially because of the large number of different maize types grown in the region. The most important of the distinct chicha types are the following: Chchullpi (or Chulpi), Kulli, Chaminco, Huaira-sara and Amarillo. The maize growing regions of Cuzco are well defined, being found in the Provinces of Quispicanchi, Paucartambo, Convención, and Anta. Within each of these

provinces, maize is grown in a few well known valleys and plateaus, of which the most important are the Vilcanota-Urubamba Valley and the Plateau of Anta. The other valleys are Marcapata, Paucartambo, and Huatanay. The two former are situated at lower altitudes in a semi-tropical region, and the latter is a small valley that joins the Urubamba River at the head of which the city of Cuzco (10,-200 ft.) is situated.

The river of the Vilcanota-Urubamba Valley—the old sacred valley of the Incas —originates in the Vilcanota range and flows due North to join the Apurimac river which flows into the Ucayali. The Ucayali, in turn, eventually joins the Marañon to form the Amazon river. However, the maize growing region in this valley is in the highlands and begins, properly speaking, at the town of Marangani (10,800 ft.). Maize is grown as far down the valley as the town of Ollanta (9,000 ft.) where the valley is constricted into a narrow canyon. Maize is also grown in the tropical part of the valley in the Province of Convención, but the types grown are totally different from typical sierra and Cuzco maize. With one exception, maize is not known in the whole of the region of southern Peru from Marangani to Juliaca and Puno, and west to Arequipa. This region includes the greater part of the high "puna" of Peru at altitudes above 10,500 ft. The single exception is a small zone off the shores of Lake Titicaca at 11,400 ft. near Puno where the lake modifies the climate slightly and Altiplano types of maize are grown. Only relatively small quantities of chicha are produced in this area.

In the whole region of Cuzco, therefore, four main groups of maize types can be distinguished: those from the tropical and semi-tropical Provinces of Convención, Paucartambo, and Marcapata; from the Ollanta—Urcos region in the Urubamba valley; from the Urcos—Marangani—Huatanay valley region at a higher altitude (9,400 ft. to a maximum 10,800 ft.); and from the plateau of Anta and other higher altitude zones with a puna climate. The most important area by far is the Urubamba valley.

The varieties grown in the Urubamba valley include the following: Imperial Blanco (also Blanco de Yucay, Blanco de Urquillos, Paraccaisara); Amarillo (also Uhina, Ubina and Ckello-sara); Mistura (also Chaminco, Chamico, Puca-Sara, Colorado, Sangre de Toro); Nueva Granada (also Rosado); Sacsa; Huaira-sara (also Maíz Negro or Morado); Chchullpi (also Maíz Dulce or Maíz Arrugado); Confite (also Reventador, Arroz, Popcorn); Pescocc-runtum (also chchuspi, Maíz Moscado, Huevo de Pájaro); Occe-sara (also Maíz Plomo). Ten of these types are different forms of the Imperial Cuzco race as described by Cutler (5): very large kernels, eight well-marked rows, grain covered tip, slight taper towards the point, slight dent and slight pointing of the kernel. These types are Blanco, Amarillo, Mistura Kulli, Sacsa (all commercially the most important and on the whole, the most used for Chicha), Nueva Granada, Huaira-sara, Capuli, Pescocc-runtum and Occe-sara. They differ from one another in color, and in the relative size of the ear and kernel. Thus, Occe-sara is a dark, uniformly gray type, while Pescocc-runtum has gray kernels as well as splashed gray and purple with a creamy white background. This is the only mottled type, and both types and Huaira are the only gray types found. The ears are somewhat smaller than the standard Imperial Blanco, and the kernels are wider in the middle than at the tip. The kernels of Pescocc-runtum are narrower on the whole than those of Occe-sara. Huaira-sara is also uniformly gray, but exactly like Blanco in every other character. Kulli is the only black type. Mistura is uniformly deep bright red; Sacsa is variegated red on yellow; Nueva Granada is white and rose-pink,

with the color placed at the sides of the kernel and rarely on the crown: Capuli has the same color pattern as Nueva Granada, but is a deep, dark red on creamy yellow. Amarillo is the only yellow type, and together with Blanco makes up the standard typical Cuzco type of maize. In all cases the endosperm is white. Cob color shows some differences, being white only in Blanco and the gray types, and pink to deep red in the others.

There are interesting and important variations in aleurone colors. Thus, Amarillo, Occe-sara and Pescocc-runtum have colorless pericarp and colored aleurone, while Blanco has a colorless pericarp and aleurone; Puca-sara, a colored aleurone and pericarp of different colors; and Granada and Sacsa, a colored pericarp and colorless aleurone. Capuli has a deep yellow aleurone and deep red pericarp, except at the crown, where the pericarp is colorless and the yellow aleurone beneath is visible through it. These types represent, therefore, five totally different pericarp-aleurone color variations.

The group of varieties grown in the intermediate zone between Urubamba and the Altiplano, are the following: Chancha, grown at Chuquicahuana, a yellow type, with small kernels; Calhuai (or Calhuay) and Sorccas, both yellow and both grown near Urcos in the Huatauay valley; Amarillo Oro; Amarillo Puntiagudo. The outstanding difference between this group and the Urubamba group is the predominance of yellow types with small, hard kernels, or with a pronounced pointing of the kernels. The pointed types also have eight rows and large kernels, while the hard-kerneled types, such as Amarillo Oro, have a tendency to 10 rows. These types have been classified by Cutler (5) as a distinct race (Uchukilla), which he described as follows: "The race includes, however, some flour and semi-flint varieties, usually yellow and often red, which are known locally by other names. The plants are small and mature earlier than other races in the same district, usually requiring 50 days from the time of planting to the appearance of the silks. The ears are small, with 8 to 10 straight rows of grains. These grains are widest about two-thirds of the distance from the base to the tip, and frequently very slightly beaked, pointed or dented. Ears of Altiplano maize which have low row numbers and a less spherical ear shape, than usual, approach Uchukilla in appearance. It is nearly always possible, however, to distinguish the few and distinct rows of nearly diamond-shaped, flattened grains of Uchukilla from the larger number of somewhat irregular rows of rounded, or slightly pointed and imbricated grains of Altiplano maize."

Finally, two special types occur in the Cuzco region and in many other parts of the Peruvian sierra. These are Chchullpi of Chulpi and Confite (or Maíz Arroz). Cutler has classified Chchullpi—which he calls Chuspillo, the Bolivian name—as a form of Valle race. This type is used for good quality and highly alcoholic chichas

CHICHA MANUFACTURE

A summary description of the process in the northern coastal region and in one of the highland regions is sufficient to illustrate the most important stages in the manufacture of chicha in Peru. The differences in method are greatest between the lowlands and the highlands. The following description is based on data obtained in the northern coastal lowlands of Peru, in the region of Catacaos in the Department of Piura, and in the highlands in Arequipa and Cuzco.

1. The Pacific Lowlands

The first step in the manufacture of chicha in Catacaos begins with the choice of good quality Alazan maize. Quality in this sense means mature kernels in good physical condition, and a minimum of mixing with other types. The cheaper and less desirable maize has varying proportions of second grade kernels, and mix-

ture with non-Alazan types, such as Maíz Serrano from the highlands and Colorado from Viru. The color of the latter is of a distinct shade of red, and it can be easily recognized in a mixture with Alazan.

The various stages in the making of chicha can be divided into two distinct parts. The first part consists in making pachucho, and jora, and the second in the making of the chicha from the pachucho. In this region of Peru, jora refers to dried, germinated maize, and pachoucho to ground or milled germinated maize. Each stage is quite complex, and a very marked specialization exists in Catacaos, where the chicha maker does not buy maize, but pachucho previously made by specialists. The pachucho is made as follows:

Soaking. The shelled maize is put into large earthenware pots full of water which are placed in a hole in the ground. The soaking takes about 12-18 hours, usually overnight. Excessive soaking turns the kernels black and causes loss of "consistency." The determination of the exact degree of soaking ("well-filled" kernels) is done to some extent by "feel," or pressure. Since the maize kernel has no semipermeable membrane, as is the case with wheat and barley, the absorption of water is uniform over the whole surface. A "well-filled" kernel, therefore, is one that has the desirable degree of turgidity as determined by pressing the kernel between finger and thumb.

Germination. The wet maize is spread in a suitable place in a layer about 2 to 3 inches thick. The most important factor at this stage is to ensure that the maize is in the dark and that the area is not exposed to wind or direct heat. Excessive drying prevents proper germination and water is sometimes sprinkled over the maize to keep it moist. Germination takes about 3 days. During this time, the maize is not moved, and any coverings, when used, must be of light weight (straw or sacking is preferred). The optimum stage is reached when most of the maize has germinated and the plumule is about ¼ inch to ½ inch long and tastes sweet.

Uniformity in the rate of germination is extremely important at this stage, and is the chief reason given locally for the superiority of Aladan for chicha. Some "grading" is done to separate the fast from slow germinating kernels especially when the range in germination time is great. There is, however, no real control exercised over temperature variations within the mass of germinating maize. The minimum and maximum temperatures for maize germination are approximately 41° F., and 14.8° F., with the optimum at 91° F. (9, 10). Maize germinates in 10 to 20 days, at 43.7° F., and in 5 to 10 days at 48.6° F. to 58.5° F. The possible temperature range is therefore very wide, and differential temperature variations in the germinating maize no doubt also account for marked variability in germination time. Every effort is made to maintain an even temperature, but this is rarely achieved with the primitive means at hand.

"Humeo." The germinated maize is heaped up in a convenient place, and the heap is carefully covered with layers of burlap or other material. For two days the heap is left untouched. The maize is said to be "humeando" or smoking. The temperature generated in the smoking heap is high enough to burn a man's hand if placed inside it. After two days, the maize has the appearance of having been thoroughly parched. It is whitish being covered with a thin layer of ash.

Drying. The germinated, parched maize is spread out in the sun, as a layer about one half inch thick and is turned frequently. Drying is continued until the maize is perfectly dry (2 to 5 days) for otherwise grinding or milling is difficult. Once the maize is dry, it is put into burlap sacks. The broken pieces of roots and seedling shoots (puño) are also very carefully gathered. The product is known as

jora. The jora is, nowadays, usually sold to millers. who produce pachucho or milled jora for sale to the chicha makers. The loss of weight between maize and pachucho is from 10 to 15%. Pachucho keeps well for about four to six weeks. The grinding of jora on a wooden "batan" (mortar) with a balanced stone has practically disappeared in Catacaos.

Chicha is made directly from pachucho. The pachucho is mixed with water and boiled in an "olla" or earthenware cooking pot. This first boiling takes about 3½ hours over a very hot fire. Water is constantly added as evaporation takes place, and the mixture is continuously stirred with a stick called a "chicula."

After boiling, the first slow cooking period follows, which takes up to 24 hours. Cooling is done by gradually reducing the fire underneath the earthenware pot. When the mixture is thoroughly cold, a very important activity follows, sometimes known as "raspeo." This is done with a "raspador," or rough-barked, wooden stick about four or five inches in diameter. The stick is placed horizontally across a pot, and handfuls of boiled pachucho are scooped out of the first pot, rubbed on the stick, and allowed to fall to the bottom of the second pot. The raspeo may take another day, and serves to "endulzar" or sweeten the chicha. It is evidently done in order to get a perfect separation of hull and starch.

The next day, the pachucho is put back into the original pot and is boiled for a second time for about 4 hours. Then it is again cooled, and left to "desfogar." Desfogar means leaving the liquid standing still for a period to clear it of smoke, and other taints, that it may have picked up during the boiling. Cooling and desfogeo is followed by the "colado," or straining. The liquid is strained through a large square piece of suitable cloth, the "sedazo," usually unbleached cotton or "tucuyo." A wire sedazo may also be used. Two people are needed, each holding diagonally opposite corners of the cloth with the right hand as tightly and firmly as possible. The left hand holds the other corner and an appropriate amount of chicha is placed on the cloth. Then, by jerking the cloth with the left hand in exact timing, the liquid is shaken sufficiently to permit a good straining. This operation is called the "taqueo." The strained liquid falls into prepared pots or "cantaros" regularly used as containers, and therefore already inoculated with yeast. Fermentation takes place in these pots for one whole day. The chicha at this stage is said to be "empuñando ácido," or, literally, "gripping acidity." So long as it tastes sweet, it is not ready to drink, but as soon as it turns "medio picantona," or semi-sharp, it is said to possess the correct flavor. The material left on the cloth is called "piqua" and is fed to chickens and pigs. Straining may also be done after the first boiling.

The chicha is divided into two layers. The uppermost clear layer is called "claro," and is sweeter and more potent than the bottom and thicker layer, or "chicha espesa" or "blanca." Since chicha is unstable, it becomes less and less sweet as time goes on, until it turns to vinegar. When sugar is added to the chicha in order to increase its alcoholic potency and quicken the fermentation process, it is added during the second boiling. The sugar is usually "chancaca" (brown sugar) or molasses.

The amount of pachucho used for chicha making is measured in "almus" one almu containing 40 lbs. of pachucho. From one almu four standard "ollas" or pots of chicha are obtained, approximately 7 gallons. Hence, a 100 lb. sack of shelled maize gives approximately two almus of pachucho, and some 14 to 15 gallons of chicha. For the best chicha pachucho alone is used, but second grade cheaper chichas are also made from mixtures of pachucho with ordinary corn meal. The maximum quantity of corn meal that can

be safely used is 20 lbs. per almu. The quality of pachucho is determined by taste and smell. The taste of pachucho is decidedly sweet, but expert chicha-makers can determine fine gradations in sweetness, texture and odor, all of which influence the ultimate quality of the chicha.

2. The Highland Region

The making of "huiñapo" (jora) in Arequipa is essentially similar to Piura, except for minor details. Some of the more important of these are due to climatic differences between Arequipa, situated at 8,500 ft. with a cool climate, and the hot, rainless desert conditions of the coast. The well-known black jora ("jora negra"), or flour from toasted maize, is also made in Arequipa. It is usual to add burnt sugar to the maize flour, which gives the resulting blend a distinct dark color and differentiates it from ordinary jora "blanca." A mixture of these two kinds of jora is sometimes used.

Huiñapo in Arequipa is made as in the coastal regions of the north, from germinated maize. The soaking takes three days and nights, and germination is obtained by ensuring that the place where the maize germinates (usually a pit called "poyo" or, more generally, "crecedera") is well covered. Germination takes about 8 days, but it may take as long as 15 days during the cold months. Drying is done in the sun. Poor drying greatly affects the quality of the chicha in Arequipa, especially during the rains. A slow drying will cause the wetter huiñapo to become "caliente" (hot), or fermented, and, therefore musty and of bad quality. Similarly, a poor chicha, called the "huiro qquegque" is produced when the plumule is too green.

Chicha is made by boiling about 30 lbs. of ground huiñapo in a "tinaja" or "olla." Stirring is done with the "ccaihuina" or "caiguina," a stick about three feet long. After the first boiling, which takes about three hours, the chicha is left to settle. The next step is to decant the liquid, but not the sediment ("crudo") into the "cconcha." These are large earthenware pots (usually four), placed permanently on a firm cement or adobe base. A wood fire is built underneath and the second boiling takes place. While the liquid is still hot, it is transferred back to the tinaja, and again back to the cconcha. This process takes some six hours. Water is added constantly during the boiling, as evaporation takes place. A mixture of chicha and water ("chuya") is sometimes added towards the end of the boiling. At this stage the straining of the liquid begins. This is done, as in the lowlands, with a piece of cloth. The residue, after straining, is called "anchi" and is given to animals. When the contents of the cconcha have been strained, the liquid is known as "chicha husma." This liquid is left to settle overnight, and is transferred to another pot in the morning after further straining. At this point, the cconcho is added to produce "chicha verde." Cconcho is day old chicha, already fermented. After an interval, a small quantity of fresh, but hot "chicha husma" is also added to the "chicha verde," a process called the "relleno." This mixture is stirred until the right temperature for fermentation has been evenly obtained throughout the mixture. The mouth of the pot, or even the whole pot is then covered up until the chicha reaches "madurez," or maturity. This chicha must be consumed the same day. After 24 hours it begins to turn rather sour, and it is then called "chicha sayana." However, the chicha sayana is not wasted, but is used in the forms of cconcho in the manufacture of the next lot of chicha, before it has turned to vinegar. If sugar is added, it is done at the chicha husma stage.

There are several differences in detail from region to region in the manufacture of chicha in the highlands. However, the principal method used in the Cuzco re-

gion, as in Catacaos and Arequipa, is by malting. Jora or huiñapo (both words are used) is made in Cuzco in the way already described, by soaking the maize in water, and allowing it to germinate. Some chicha from chewed jora is also made (muko), but this method is much commoner in the Puno and Lake Triticaca region of Peru than in Cuzco. According to Cutler and Cardenas (6) and others (16), the use of "salivated" maize for chicha making is quite common in Bolivia, and they have described the process in detail for the Cochabamba region. The method used in Cuzco and Puno is essentially similar to that used in Cochabamba, but the chewing is traditionally done by young girls, who have never chewed coca. Other types of chicha in small quantities, especially from mani (*Arachis hypogaea*), frutilla (*Fragaria chilensis*), molle (*Schinus molle*), and quinoa (*Chenopodium quinoa*). A type of chicha called tekhte, is made from a blend of Maíz Blanco and quinoa.

The preparation of the chicha from huiñapo is done as in Arequipa. However, the amount of huiñapo used for a day's consumption (a "hraki") is about 40 lbs. After the first boiling, the unfermented chicha ("uppi") is strained into the hraki. The straining is done by the use of a basket filled with ichu grass. A small amount of one day old chicha is added to the uppi. The hraki is then covered and fermentation takes place overnight. The uppi then becomes "hanchi." The hanchi is then boiled for a second time to give the "sege," the liquid obtained after the second boiling, and the "sutuchi," which is the final residue used for animal feed. Sugar is sometimes added after this boiling, while the chicha is cooling and settling. When Chaminko variety has been used, the chicha has a reddish tinge.

DISCUSSION

This brief description of some maize types of Peru, and the process of making chicha in three regions, indicates that, although each region uses its own characteristic types of maize, the technology of chicha manufacture is essentially the same in all of them. The making of chicha in relation to the maize types used, appears to be much more closely associated with the production of jora or huiñapo than with the fermentation process itself. At the same time, the quality of jora and the amount produced is largely dependent on uniformity of germination rate. Uniformity of type, with reference to the types of maize used for chicha, means uniformity of germination rate. This uniformity has been obtained in Peruvian maize by careful selection over a long period of time. This characteristic of the maize types used for jora is, in practice, considered of primary importance by the makers of jora, and appears to be fundamental in the differentiation of maize types used for chicha. The external appearance of the kernel is used only as a "marker," so as to distinguish maize types with varying rates of germination. The least desirable maize is a mixture of types. It is tentatively suggested that the study of germination rates may serve as an additional tool in the classification of maize into races (16), their origin, and the relationship between them.

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Grass Breeding and Livestock Production[1]

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INTRODUCTION

In a world of hungry mouths, increased production from grassland is of universal economic and humanitarian concern (68). Livestock production from grassland depends upon many factors. One very important, yet little recognized factor is heritable variation within the grass species utilized by livestock (Fig. 1). Grass breeders have taken advantage of this heritable variation to develop distinct and apparently valuable varieties of many species (23, 24, 42). A considerable body of agronomic data has accumulated on the degree of varietal differentiation which may be expected in such obviously valuable characters as seedling vigor, (49, 52, 63) disease and cold resistance (5, 10, 12, 14, 25, 43, 62) persistence under defoliation (12, 22, 25, 41, 70, 71) forage quality (2, 3, 5, 13, 22, 43, 51, 53, 67, 69, 72), and forage production (6, 12, 13, 17, 22, 25, 35, 36, 43, 66, 67). Facilities have not been available to most breeders, however, for variety evaluations in terms of increased animal production, the main economic goal of their research. In recommending varieties they have had to extrapolate from agronomic evaluations. They have been comforted but not satisfied by studies correlating such data with pasture figures. They have found that varieties maintain their identities whether in pure stand or in mixtures (57). They know that yields measured under grazing have been closely correlated with forage yields determined from clipping studies (6, 13, 54, 66). Forage yields under grazing in turn have been closely correlated with animal production (36, 54, 65, 66, 74, 75). Most available evidence suggests that the best varieties in nursery and field plot tests are also among the best varieties for pasture use, particularly pastures managed for maximum productivity (66). Although suggestive of pasture potentials, forage yields and other such agronomic evaluations do not give final answers. Such answers *must* come from animals grazing the forage (48).

Pasture management research has been concerned with systems of grazing, soil fertility studies and feed supplements. Considerable interest has also been shown in comparisons of various species and species mixtures. Information thus obtained has been used to increase production. Relatively few studies have been made on possible production increases from use of appropriate varieties within adapted species. This pasture production factor has been so far exploited to only a limited extent.

Are genetic differences within forage grass species important in animal production? How good are "improved" varieties? Although shortages of research facilities and higher priorities for other types of pasture research have limited the amount of data available, there are some answers. The purpose of this review is to summarize available information and to draw some conclusions on the importance of varietal differences in grasses to animals grazing those grasses.

STUDIES IN THE UNITED STATES

Most of the pasture and grass breeding research in the United States has taken place only within the past quarter century.

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Fig. 1. A variable population of blue grama in a space-planted nursery at Woodward, Oklahoma. Many species of grass show even greater variation. The breeder exploits this variation by selecting and combining desirable types to produce improved varieties.

Active research programs are now underway in every state and pasture production is steadily rising. Many of the most striking examples of progress are in the southeastern states where a changeover from continuous row cropping to pasture rotations and improved permanent pastures is taking place. The work of Dr. G. W. Burton and associates at the Georgia Coastal Plain Experiment Station, Tifton, Georgia, is playing an important role in this changeover. Much of the available American data on animal production differentials among grass varieties has been obtained at Tifton or is concerned with Tifton varieties.

Perennial grasses

Bahiagrass (*Paspalum notatum* Flugge). Various introductions of this South American species have proved valuable as upland pasture in the southeastern states. Several distinct types have been introduced (4). They fall into four major categories (74): 1. short narrow leaves (example 'Paraguay'); 2. long narrow leaves (example 'Pensacola'); 3. short broad leaves (example 'common'); 4. intermediate long leaves (example 'Argentine').

'Pensacola' bahia illustrates a situation which has been common with many pasture species—recognition, increase, and release after agronomic evaluation of a naturally occurring strain. The original plantings of this variety were from seeds collected near the dock area in Pensacola, Florida (19). Its performance in nursery and small plot plantings led to release as a recommended variety in Florida in 1944 (24). Pasture evaluations followed its release. It has proved itself as an outstanding variety wherever adapted.

At Tifton, Georgia, average beef yield

per acre from Pensacola over the 1943-1948 seasons was 208 pounds. During the 1944-1948 seasons, beef production from 'Paraguay' under equivalent management averaged only 105 pounds per acre (74). In Florida, Hodges, Jones, and Kirk (30) found that average beef production over the 1945-1949 seasons was 139 pounds per acre from 'Pensacola' compared with 86 for common. During the 1949-1951 seasons 'Pensacola' averaged 152 pounds of beef to common's 74. The 'Argentine' variety produced 102 pounds of beef in 1951. Under higher fertility levels (900 pounds 6-6-6 vs. 500) production in 1952-1954 averaged 215 and 216 for 'Pensacola' and 'Argentine' compared to 149 for the common (31). In a different Florida comparison by Jecers, 'Pensacola' produced 703 pounds of beef compared with 487 for 'Argentine' (39).

Although already superior to known bahiagrass types, 'Pensacola' itself has been improved. 'Tifhi 1' is a first generation hybrid of two plants selected from 'Pensacola' for their ability to produce especially vigorous and desirable progenies. In duplicate 2-acre pastures over a 4-year period at Tifton, Georgia, 'Tifhi 1' produced an average yield of 460 pounds of beef per acre while 'Pensacola' produced 390 (28).

Bermudagrass (*Cynodon dactylon* (L) Pers). Bermudagrass is of world-wide distribution from the tropics to milder parts of the temperate zones as a pest in cultivated fields and an inhabiter of waste places (29). Only in recent years has it come to be recognized as a worthwhile pasture grass. In the United States much of that recognition has come since the release of 'Coastal' bermudagrass (Fig. 2). 'Coastal' is a most remarkable example of how a really good variety can become recognized and widely used in a short time. Released in 1943 (24, 56) this hybrid has since been planted on over

Fig. 2. Herefords grazing 'Coastal' bermudagrass at Tifton, Georgia. (Photo courtesy of G. W. Burton).

3 million acres across the Southern United States[3] in spite of the fact that it must be propagated vegetatively! Wherever adapted it has proven itself resistant to environmental hazards such as disease or periods of drouth, and superior in forage production potential (6).

First comparisons between 'Coastal' and common bermudagrass as pasture for steers were made at Tifton, Georgia. Five year average yields of beef per acre were 278 pounds for 'Coastal' and 162 for common under the same conditions of fertility and management (6). Later studies showed that 'Coastal' gave a tremendous production response to nitrogen fertilization. Two additional pounds of beef were produced per acre for each pound of nitrogen added, up to 200 pounds per acre (6).

At Clemson, South Carolina, a 3-year comparison of 'Coastal' with common (fertilized with 188 pounds of nitrogen per acre) gave average beef yields per acre of 552 and 407 pounds, respectively. In addition to beef from the grazing animals, 'Coastal' produced 1.29 tons of hay per acre each year compared to 0.22 from the common pasture (21). At Edisto, South Carolina, rates of 100, 200, and 400 pounds of nitrogen per acre were applied to continuously grazed bermudagrass pastures. Over the 2 years 1958-59, 'Coastal' averaged 368, 788 and 1,000 pounds of beef per acre compared to 348, 587, and 804 from the common.[4] At the Wiregrass substation in Alabama (1) 'Coastal' produced 254, 318, and 483 pounds of average steer gain per acre with 0, 80, and 160 pounds of nitrogen per acre over the 1953-1955 seasons. Comparable gains from common were 102, 226, and 295 pounds of beef.

In Texas studies, 'Coastal' gave increased forage yields with increases in nitrogen at rates up to 1,200 pounds per acre and gave increased protein yields at rates up to 1,800 pounds of nitrogen per acre (20)! Recent Georgia studies suggest that by feeding dehydrated pellets of 'Coastal' from high yielding heavily fertilized fields, beef yields up to a ton per acre might be produced (76).

Blue grama (*Bouteloua gracilis* (HBK) Lag ex Steud). Blue grama is one of the famous native "short grasses" of the North American Great Plains. Its range extends from Canada to Mexico and from Wisconsin to Nevada (29). It is an excellent grass and is used in most of the native grass seed mixtures in the Southern Great Plains area. All of the seed presently marketed is harvested from native stands. Sources vary from year to year. Although its wide range includes many ecotypes (26) the exigencies of seed needs and the generally low levels of production in the area due to low rainfall have tended to minimize the importance of genetic differences. Possibilities for exploitation of natural variation have been enhanced by development of techniques for profitable seed production (50) and active breeding programs are underway.

Studies of native North American grasses from various sources have shown that, in general, accessions from south of the testing station produce more vegetative growth and total forage than those from local or especially northern origins (61, 64). Some evidence of the possible importance of ecotypic differences in blue grama is provided by data from the Southern Plains Experimental Range near Fort Supply, Oklahoma[5]. (Fig. 3) Liveweight gains per acre by Hereford steers grazing yearlong were measured on pastures seeded to three sources of blue grama. One pasture was seeded in 1944 with seed harvested near Dumas, Texas. This pasture was also seeded to sideoats grama (*Bouteloua curtipendula* (Michx) Torr) and to two cool-season species. Over the

[3]G. W. Burton, personal communication.

[4]E. C. Godbey, personal communication.

[5]E. H. McIlvain, unpublished data.

Fig. 3. A pasture seeded to blue grama on the Southern Plains Experimental Range near Fort Supply, Oklahoma. Blue gramas from different sources vary in productive potential.

years, the contribution of the associated species was greatly reduced. Most of the production in recent years has been from blue grama. The other two pastures were seeded side by side in 1950 to blue grama alone, one with seed harvested near Marfa, Texas, the other with seed harvested near Bushland, Texas. All three pastures were on similar soil types under comparable conditions and management. Approximately 50 percent of the available forage from each pasture during the period 1952-1959 was blue grama, the remainder primarily from weedy grasses and forbs.

Average yearlong beef production per acre for the 7 years 1952-1959 was 49.8 for the Dumas source, 59.8 for the Bushland source, and 62.1 for the Marfa source. Dumas, Texas, is approximately 50 miles farther south than Fort Supply, Oklahoma, Bushland is 100 and Marfa 400. Beef production ranked in the same order that nursery studies would have predicted. The Marfa source was actually more productive than these averages indicate. Initial differences in seed quality were such that although the Marfa was seeded at half the Bushland rate it had a thicker and more vigorous stand and would have been grazeable 3 months earlier. Some potential production from the Marfa source was thus lost while waiting for sufficient growth from the Bushland for grazing. This greater initial production from the Marfa is shown by yields of 109 pounds of beef compared to 88 for the Bushland in the first grazing year. The thinner stand from the Bushland seed source was invaded during the middle years of this test by sand dropseed (*Sporobolus cryptandrus* (Torr) A Gray) in sufficient quantities to increase beef production, (conditions at this time were specially favorable to sand dropseed) thus helping to narrow the gap between it and

'Marfa.' Marfa and Dumas sources maintained blue grama dominance throughout.

Annual Grasses

Pearl millet *(Pennisetum glaucum* (L) R (Br). Pearl millet, often known as cattail millet, is widely used in the southern United States as an excellent temporary summer pasture. Common types tend to get tall and stemmy by the end of the grazing season. An active breeding program with this species has been conducted at Tifton, Georgia, for many years by Dr. Burton. By crossing other selections with an unusual plant having short internodes and selecting from the ensuing generations for short leafy plants, he developed the variety Starr (24). Burton and DeVane (9) compared summer pasture productions of common and 'Starr.' Common furnished 128 animal days and 223 pounds of beef per acre. 'Starr' furnished only 124 animal days, but 275 pounds of beef per acre. Daily steer gains were 1.7 pounds on common and 2.2 pounds on Starr.

Continued grass breeding research by Dr. Burton led to release in 1958 of 'Gahi-1' cattail millet (Fig. 4) (24), an F_1 hybrid which starts faster in the spring, recovers faster after grazing, yields more forage and is more efficient in fertilizer and water use (8). A North Carolina study by H. D. Gross using dairy cattle showed that production of total digestible nutrients was 4,647 pounds per acre for 'Gahi-1', 3,653 for 'Starr' and 3,476 for common (8). Studies at Tifton have in-

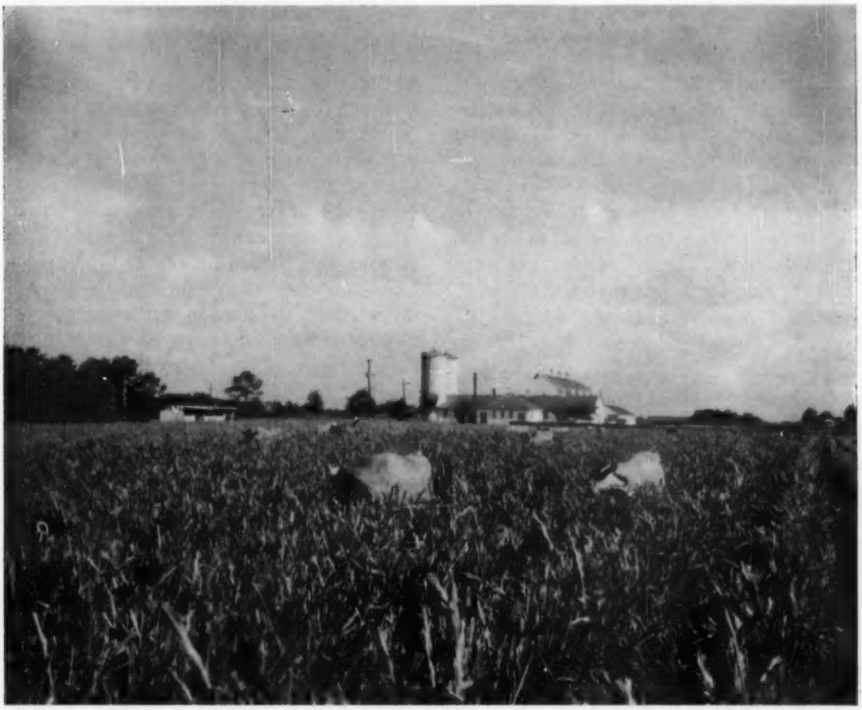

Fig. 4. 'Gahi I' millet at Tifton, Georgia. 'Gahi I' is an outstanding example of improvement of an annual forage crop. (Photo courtesy of G. W. Burton).

dicated that dairy cows on 'Gahi-1' will outproduce those on 'Starr' (8).

Oats (*Avena sativa* L). Fall planted small grains have long been used in the southern half of the United States as supplemental pastures for the winter season. When used to full advantage they are excellent producers of meat and milk. More and more farmers are planting cereals for use as pasture alone. Data obtained by Marshall (55) in Florida indicate the production which may be obtained. In a two year study, liveweight grains per head by Jersey heifers grazing 'Southern' and 'Camellia' oats averaged 237 and 234 pounds, respectively. Marshall concluded that the two oat varieties were essentially of the same pasture value, both putting excellent and economical gains on growing stock.

Rye (*Secale cereale* L). Times of peak production often vary among forage crop varieties and a particularly interesting difference in peak production time is that between 'Elbon' and Balbo' rye. In clipping studies conducted in Oklahoma by Huffine, et al. (34), on irrigated small grains, 'Elbon' produced 16% more forage and 21% more protein than 'Balbo' in the fall. In mid-winter, forage production from 'Elbon' was 4-5 times that from 'Balbo.' In spring, however, production from 'Elbon' was only 70% of that from 'Balbo' (34).

A companion study by Elder (18) during this same period showed that gains by Hereford steers grazing these two varieties were closely correlated with forage and protein yield values. 'Elbon' produced high gains during the early part of the grazing season, 'Balbo' in the last part (Table 1). Because of its great spring growth, total gains were somewhat higher from 'Balbo' than from 'Elbon', 230 compared with 216 pounds. Since shortages of green feed are most crucial in fall and mid-winter, 'Elbon' rye has some unique advantages for winter pastures in Oklahoma. The fact that no adjustments in stocking rate were needed on the 'Elbon' pasture would also be important to many farm operators.

STUDIES IN THE BRITISH ISLES

Some of the earliest research on breeding grasses specifically for improved pasture was done at the Welsh Plant Breeding Station at Aberystwyth. Early work on techniques by Jenkin (40) and Stapledon (72) and their description in 1931 of breeding systems they used (41, 73) provided the base upon which later grass breeders the world over have built. Aberystwyth strains of the important British forage grasses are in wide use in Great Britain and Ireland (42, 43). Various other varieties of commercial or foreign origin share the market with the Aberystwyth products. Relative merits of these various sources are of great interest and several studies have been set up to com-

TABLE 1
BALBO VS. ELBON RYE FOR PASTURE[1]

Grazing dates	Balbo			Elbon		
	Animals per acre	Daily gain	Beef per acre	Animals per acre	Daily gain	Beef per acre
11/1/57—12/4/57	.7	2.0	43	1.0	2.1	73
12/5/57—1/7/58	.7	1.9	40	1.0	2.2	75
3/7/58—4/10/58	1.7	1.4	81	1.0	.9	32
4/11/58—5/20/58	1.7	1.0	66	1.0	1.0	36
			230			216

[1]Data from W. C. Elder in "1958 Annual Report of Progress in Research on Pasture Improvement," conducted by the Oklahoma Agricultural Experiment Station in cooperation with the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture.

pare them in pasture mixtures under pasture conditions.

Orchardgrass (*Dactylis glomerata* L). One of the earliest published comparisons of selected versus commercial varieties of pasture grasses in terms of animal products was made at Aberystwyth by Jones (45). He found that in the first harvest year, sheep made higher gains on selected strains of orchardgrass than on commercial sources. After 3 years of grazing only 14% of the herbage on the commercial plots was orchardgrass compared with 42% for the selections. Gains in the second and third year however, were higher than the commercial plots. He attributed the extra second and third year gains to the variety of forage available from invading plants in the commercial swards.

Perennial ryegrass (*Lolium perenne* L). Perennial ryegrass has been seeded for pasture in Great Britain since the 17th century (43). It has become so identified with British pastures that in other European countries it is often called "English ryegrass." In combination with white clover (*Trifolium repens* L), particularly under cool moist conditions, it is capable of very high production and is the preferred grass species for permanent or long time pastures in much of Great Britain and Ireland.

One of the most widely used commercial seed sources in Great Britain is 'Irish' perennial ryegrass. Although stemmy and relatively short-lived it starts fast in the seedling year and produces good early season feed (42). The various Aberystwyth strains have been selected for leafiness, disease resistance and long life under grazing. 'S23' and 'S101' were developed from old pasture sources and are noted for leafy late growth and persistence. 'S24' was selected to provide early feed as a direct competitor to the Irish type strains (42).

Sheep Production in Wales

'S24' was compared with 'Irish commercial' ryegrass at Aberystwyth by Hughes (36). Three basic mixtures were used. In each mixture one seed lot included 'S24' and one lot included 'Irish.' Best producing mixture for both varieties was the simplest—perennial ryegrass and white clover. Most of the grass production in each of the mixtures after the first year was from perennial ryegrass. Comparisons were made in terms of forage yield under grazing by sheep and in ewe-days of grazing obtained. Data were obtained from nitrogen-fertilized and non-fertilized plots. 'S24' was the best producer in spring and autumn while 'Irish' produced most at mid-season. At all seasons, 'S24' gave better response to nitrogen (Table 2). Fertilization of 'S24' gave a 22% increase in ewe-days while the increase from 'Irish' was only 17%. Comparable figures for forage yields were 43 and 29%. 'S24' resisted invasion by unsown species better than 'Irish' and mid-season yields from 'Irish' plots were aided by mid-season growing volunteers, especially in the third season. In one season 'Irish' was badly affected by rust while 'S24' was scarcely affected.

Jones (46, 47) compared seeded pastures with unimproved pastures in hill

TABLE 2

SEASONAL PRODUCTION FROM PASTURE PLOTS AT ABERYSTWYTH, WALES, 1948-1950[1]

	Spring		Mid-season		Autumn	
	Ewe-days	Forage yield	Ewe-days	Forage yield	Ewe-days	Forage yield
Fertilized	68	82	102	99	66	63
Check	78	81	109	110	75	72

[1]Values are for Irish perennial ryegrass mixtures in terms of S24 mixtures at 100. (Adapted from Hughes, WPBS Bul. Ser. H, No. 18, 1956).

country in Wales. Seeded pastures were of two types, one mixture including Aberystwyth strains of perennial ryegrass, orchardgrass and timothy (*Phleum pratense* L), the other containing commercial sources of the same grasses. For the period 1945-1951 unimproved pasture produced 298 pounds of lamb per acre, the commercial mixture 747 pounds and the Aberystwyth strains 840 pounds. Number of lambs reared per 100 ewes were 80, 101, and 102. Lamb grades were in the same proportions (46). For the period 1950-1956 the annual lamb production per acre averaged 52, 142, and 155 for unimproved, commercial strains and Aberystwyth strains, respectively. Lambs reared per 100 ewes were 79, 111, and 115 (47). Seeded pastures were clearly superior to unimproved hill pastures and pastures seeded to bred strains to those seeded from commercial sources. Carrying capacity, lambing percentages, lamb weights, and grades were all highest from seeded pastures of Aberystwyth selections.

Beef and Mutton Production in Ireland

Across St. George's Channel from Aberystwyth, at Wexford, Ireland, another long-time comparison of a pasture mixture of commercial sources with one containing only Aberystwyth strains was set up in 1949 (59, 60). Pasture plots were grazed by beef cattle followed up with sheep. Liveweight gains from both classes of livestock were determined at intervals through the season. Perennial ryegrass in the Aberystwyth mixture was 'S23' and 'S101.' In the commercial mix it was 'Irish.' The perennial ryegrass very quickly took over from other seeded grasses in both mixtures and the test became essentially a comparison of the two perennial ryegrass types. As the years went by, invading species and white clover provided more of the feed on the commercial plots than the Aberystwyth plots. 'S23' and 'S101' produced a closer turf and resisted invasion better than did 'Irish.'

For the first three study years all plots were fertilized equally, with average nitrogen applications at 51 pounds per acre. During the next four years half the plots had 164 pounds of nitrogen per acre, half none. Production from the unfertilized plots in this period was at equivalent levels to the earlier years. When figures from these plots are used with the first three years' data to get a seven year average (Table 3), they show that 'Irish' produced 31 pounds more liveweight gain per acre in the spring while the Aberystwyth strains outyielded 'Irish' by 20 and 4 pounds per acre in mid-summer and fall, respectively.

The 'S23,' 'S101' combination gave a much greater response to nitrogen than did 'Irish' (Table 4). Total production from the two types was approximately the same at low fertility levels, but with the high nitrogen the Aberystwyth strains outyielded commercial by nearly 60

TABLE 3

SEASONAL AND ANNUAL LIVEWEIGHT GRAINS PER ACRE FROM CATTLE AND SHEEP GRAZING TWO EQUIVALENT GRASS-CLOVER MIXTURES. WEXFORD, IRELAND 1950-56. ONE MIXTURE (C) COMMERCIAL SOURCES BASED UPON IRISH PERENNIAL RYEGRASS, THE OTHER (A) ABERYSTWYTH STRAINS BASED UPON S23 AND S101 PERENNIAL RYEGRASS.

	Liveweight gains in pounds per acre*							
	April-May		June-Aug.		Sept.-Oct.		Annual	
Class of stock	C	A	C	A	C	A	C	A
Cattle	205	178	102	116	69	73	376	367
Sheep	42	38	38	44	17	17	97	99
Total	247	216	140	160	86	90	473	466

*First 3 years pastures lightly fertilized (Prendergast and Brady, Ireland Dept. Agric. Jour. 49, 1952-53) remaining 4 years non-fertilized (Prendergast, Barry, and Brady, Ireland Dept. Agric. Jour. 54, 1957-58). Data calculated from values given by authors).

pounds of animal gain per acre. Average annual liveweight gains per 100 pound nitrogen application were 138 for the bred strains and 115 for the commercial sources.

Beef Production in Ireland

Prendergast (58) compared Irish commercial, 'New Zealand certified,' 'Glasnevin' and 'S23' perennial ryegrasses in mixtures with white clover at 21 locations in Ireland. Comparisons were made in terms of "grazing day" units equated to 2½ year old cattle. At most locations all of the grazing was by beef or dairy cattle. 'Irish' produced the most grazing in the seeding year, but 'New Zealand' proved slightly superior over the succeeding four year period. Most striking differences were in seasonal production between early and late strains (Table 5). Total production was somewhat low for 'S23' because of its slow start each year. The other three varieties were very close.

Late types were much more persistent and resistant to invasion by weedy species than the two early strains, 'S23' being particularly good. 'S23' was also most free from rust although all had varying degrees of infection depending upon year and location. At the end of the fifth year the average numbers of perennial ryegrass tillers per 4″ x 4″ turf were 12, 18, 33, and 43 for 'Irish,' 'New Zealand,' 'Glasnevin,' and 'S23,' respectively.

TABLE 4

COMPARATIVE RESPONSE BY COMMERCIAL (C) AND ABERYSTWYTH (A) PERENNIAL RYEGRASS MIXTURES TO NITROGEN UNDER MIXED GRAZING BY CATTLE AND SHEEP, WEXFORD, IRELAND, 1953-1956 (ADAPTED FROM PRENDERGAST, BARRY, AND BRADY, IRELAND DEPT. AGRIC. JOUR. 54, 1957-1958).

	Annual liveweight gains in pounds per acre			
	Nitrogen		No nitrogen	
Class of stock	C	A	C	A
Cattle	480	537	348	345
Sheep	187	177	130	142
Total	667	714	478	487

Beef Production in England

Davies and Williams (16) compared seeded pastures with old permanent pastures at various sites in England. They found that seeded pastures were equal to the old stands or superior to them in beef production. On some sites comparisons were made between 'Irish' and bred strains of perennial ryegrass in their basic mixtures. For the first 2-3 years total production from the two types was similar at most locations (15, 16). No figures were available on seasonal differences. In a study at Norfolk, average gains from the mixture with 'Irish' were 215 pounds of beef per acre compared to 194 for a mixture based on 'S23' and 'New Zealand certified' perennial ryegrass. The authors suggested that the reason for the extra gains from the 'Irish' mixture was the greater production from orchardgrass and white clover, both of these species being especially valuable on this site. Bred strains tended at all sites to form dense swards which suppressed growth of other seeded and invading species.

Beef Production in Scotland

Hunt and Thomson (37) compared commercial and bred mixtures based upon 'Irish' and 'S23' under grazing by beef animals. Because of the aggressiveness of the ryegrass the comparison was essentially between these two perennial ryegrass sources. Average liveweight gains

TABLE 5

AVERAGE PRODUCTION IN "GRAZING DAY" UNITS PER ACRE 1955-58 AT 21 LOCATIONS IN IRELAND FROM FOUR SOUBCES OF PERENNIAL RYEGRASS GROWN WITH WHITE CLOVER. (DATA FROM PRENDERGAST, JOUR. BRIT. GRASSL. SOC. 14: 238-243, 1959).

	Early varieties		Late varieties	
Period	Irish	New Zealand	Glasnevin	S23
Spring	91	90	71	66
Mid-season	97	99	108	106
Autumn	62	64	71	72
Total	250	253	250	244

were 469 pounds of beef per acre from 'Irish' and 492 from 'S23.' 'S23' was best late in the season, 'Irish' during the early part. The denser turf of 'S23' would have been more suitable for winter grazing by sheep. After 4 years 'S23' had more than twice as much cover as 'Irish.' Forage yields from the two mixtures were very similar—5,102 for 'Irish,' 5,112 for 'S23,' but the leafier 'S23' produced 934 pounds of protein compared with 879 from 'Irish' and provided an average of 370 grazing days compared with 322. The authors suggested that the seasonal production peaks of each could be fitted into a productive grazing scheme involving separate pastures.

Milk Production in England

Forage quality is particularly important to milk production and a study by Ivins, Dilnot and Davison (38) using identical twins demonstrated differences among strains. They compared the simple mixture 'S23' perennial ryegrass—white clover with 'Irish' perennial ryegrass-white clover. Milk production per acre from 'S23' was 5,430 pounds compared to 5,104 from 'Irish.' Average daily intake per cow was less from 'S23' than from 'Irish' (23.8 pounds dry matter versus 25.7) but daily milk production per cow was greater (31.9 pounds versus 30.4). Evidently the greater leafiness bred into 'S23' was making a significant quality contribution, which expressed itself in more milk per acre.

STUDIES IN AUSTRALIA

Beef Production

Rhodesgrass (*Chloris gayana* Kunth). Christian and Shaw (11) compared two morphologically different types of rhodesgrass with and without alfalfa as producers of beef. The types were 'commercial,' an early, bunch, open type; and 'Kenya,' a very late spreading type. Grazing was fairly heavy and animals lost weight in some grazing periods. Net gains per acre in eight grazing periods from January 1946 to July 1948 were 380 pounds of beef per acre from 'commercial' and 402 pounds from 'Kenya.' The authors concluded that there was no essential difference in production capacity between these sources although 'Kenya' was distinctly better for late grazing. Growing these grasses with alfalfa increased beef production but did not change their values in relation to each other.

DISCUSSION

Studies with many grasses under many conditions and at many locations have demonstrated that genetic differences within forage grass species can make significant differences in animal production. Effects of varying grass genotypes upon animal production can be almost unbelievable. 'Coastal' bermudagrass, for example, seems capable within its region of adaptation of producing 100 more pounds of beef per acre than common *at any equivalent level of* fertility or management (1, 6 21)!

Differences within species are sometimes even more important than differences between species. 'Pensacola' bahiagrass will outyield common bermudagrass at all but the highest fertility levels, yet 'Coastal' bermudagrass will outyield 'Pensacola' (1, 74). As more information about genetic differences in grass production potentials is acquired, it will become less and less possible to generalize about whole species. Maximum production from pasture depends upon fitting together the site, the management, the breeds of animals and the varieties of grass. When these factors are in balance for the particular level of production desired, maximum efficiency may be obtained. Ignoring the potentialities or the requirements of any one of them will mean lowered production and, probably, lowered economic returns.

In general, improved varieties are best

adapted to intensively managed pastures planned for maximum production. Indeed, top production cannot be obtained without using the best genetic material available. Yield responses of improved varieties to inputs of management are usually far greater than those of common sources. Several examples of extra response per unit of nitrogen have been presented (1, 6, 36, 60). In some cases the significant production increases associated with improved varieties were chiefly at high fertility levels. The studies at Wexford, Ireland (59, 60) are a case in point. Even there, however, there were differences in seasonal production and maintenance of sward which would favor the bred strains irrespective of total yields.

The data on blue grama at Fort Supply, Oklahoma, show that genetic differences can be important even at low productivity levels. Although native ranges and native grasses in Oklahoma are low in productivity compared to intensively managed pastures and pasture species under more humid conditions (27) effective increases in animal production from reseeded land can be made by selection of the best adapted varieties. Certain grass varieties may even be especially well adapted to low fertility. In Oklahoma, 'Greenfield' bermudagrass is recommended for low fertility sites while 'Midland' is superior at moderate to high levels and under intensive management (17).

Obviously, increases in total animal production will be associated with increases in available forage. In many cases, however, the superiority of improved varieties may be due to more subtle differences. Forage quality plays an important role in pasture value. Stephens (74) found that it took only 41 pounds of green 'Pensacola' bahiagrass to produce a pound of beef while it took 65 pounds of 'Paraguay' for the same result. In this case 'Pensacola' also produced more forage, but animal production would have been higher on the 'Pensacola' even with the same forage yields. The extra milk produced per pound of leafy 'S23' perennial ryegrass compared wtih stemmier 'Irish commercial' is another example of quality effect (38). Extra beef production from Aberystwyth strains in Scotland in the study by Hunt and Thomson (37) appeared to be mostly due to quality differences. Leaves are higher than stems in nutritive value and generally more avidly eaten by animals (53, 69). Increases of leaf can lead to more rapid and efficient animal gains through both higher food values and greater consumption rates. Selection for leafiness has been successful in most grass species investigated (12, 25, 51, 53, 69). In most cases improved varieties also exhibit greater resistance to foliar diseases and hence retain leaf quality better since diseased leaves rapidly lose their nutritive qualities (5).

Seasonal slumps in production have always posed pasture management problems. Many improved varieties reduce or eliminate these problems by either producing more forage in slack periods or maintaining better quality at those times. The extra growth of 'Elbon' rye in Oklahoma during fall and winter and the late summer production of 'S23' and 'S101' perennial ryegrasses in Great Britain (18, 34, 36, 37, 58, 59, 60) are examples. Quality differences in terms of either a small increment of green growth during "dry grass" periods or retaining higher nutritive values in the cured state can be very important (75). On native ranges in the Southern Great Plains of the United States, nutritive value of the native grass becomes borderline or deficient as the seasons progress into winter (27). There are genetic differences in the amount of loss or retention of quality and it seems entirely possible to develop varieties which may reduce the need for expensive supplements on reseeded pastures (53).

Adaptation of pastures to requirements of particular cultural systems is made easier by use of varieties tailored for fit.

'H_1' short rotation ryegrass was developed by Corkill (12, 13) to fit a definite type of management need in New Zealand. 'New Zealand certified' perennial ryegrass and the 'S23' and 'S101' strains in contrast, are examples of varieties fitting longtime permanent pasture (42).

Problems of essential element deficiencies or of toxic substances lend themselves to solution through use of proper varieties. Johns (44) showed that in New Zealand, varieties of perennial ryegrass differ greatly in their iodine content irrespective of the iodine content of the soil. Goiter is a problem with sheep in certain areas of New Zealand. Johns stated that it need not be a problem if the proper varieties are grown. He also suggested that problems of cobalt deficiency might be eased in the same manner.

Workers with sudangrass (*Sorghum sudanense* (Piper) Stapf) have been successful in reducing the hazards of prussic acid poisoning to animals grazing this excellent summer annual. Early work at Wisconsin (32, 69) leading to the development of the Piper variety with its low prussic acid levels, is a classic example of making over a crop by breeding.

In certain species such as tall fescue (*Festuca arundinacea* Schreb) and weeping lovegrass (*Eragrostis curvula* (Schrad) Nees) palatability is at a low enough level to make pasture management problems. Buckner (2) and Buckner and Fergus (3) working in Kentucky, have shown that varieties of tall fescue can be developed with higher palatability than common. Definite preferences by steers for certain varieties of weeping lovegrass have been demonstrated by the author in Oklahoma.[6]

CONCLUSION

Whether in terms of greater production or more efficient operations the contribution which grass breeding research has made and will continue to make to the livestock producer is a very substantial one. How substantial varietal effects can be has been demonstrated. Use of the proper variety has given up to 100% increases in production with no other change in management (1, 6, 30, 74). Mere existence of a variety does not, however, guarantee its superiority (11, 16, 55). The final test is always the animal (48). Answers from such testing have proven beyond a doubt that breeders have generally been successful. Their work promises still greater success.

As a final statement in a review of this nature no better words could be found than those used by Dr. F. R. Horne (33) in a presidential address to the British Grassland Society "... I hope I have said enough to suggest to you that, when you are next looking at grassland, you should consider the inherited characters of the sward which may well be the basic factor in production."

[6]W. R. Kneebone, unpublished data.

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Revegetation of Stripmined Bauxite Lands in Hawaii[1]

O. R. YOUNGE and J. C. MOOMAW[2]

Introduction

The State of Hawaii has an estimated 330 square miles of bauxite deposits with a total volume in excess of 500 million tons of aluminum oxide. Three sizeable deposits occur on the islands of Kauai, Maui and Hawaii, Fig. 1. The bauxites on Kauai and Maui are primarily crystalline gibbsite which can be extracted with procedures currently in use. The bauxites on the island of Hawaii, which comprise about two-thirds of the known ore volume, occur as colloidal gibbsite, for which no commercial extraction procedure is presently known.

The commercial potential of the Hawaii bauxites has been recognized only since 1955. No mining of the ores has taken place as yet, and signs of early development are lacking. However, the Legislature of the Territory of Hawaii gave recognition to the mining potential and the associated problems in 1956 by appropriating funds for the investigation of the mineral resource of Hawaii and the conservation and rehabilitation of mined lands (20).

Occurrence and Formation of Bauxites

The Hawaii bauxites are mostly reddish brown, soft earthy materials, bearing little resemblance to the general concept of mineral ores as being hard rock-like material with metallic lustre. Perhaps because of this unprepossessing appearance the bauxites went unrecognized until recently.

Aluminum occurs in Hawaii bauxites mostly as hydrates, chiefly as the trihydrate of aluminum oxide, gibbsite, $Al(OH)_3$. This identification has been based on the high content of aluminum reported for Hawaii soils by Hough and Byers (15); Hough, Gile and Foster (16); and Sherman (29, 32). Further identification of the mineral was made by Matsusaka (22) through differential thermal analysis, and by Tamura, Jackson and Sherman (33) by means of x-ray diffraction methods. Cline, *et al.* (3) recognized that aluminum, which was high in concentration, was a dominant mineral in soils classed in the Humic Latosol and Hydrol Humic Latosol groups. This led in 1955 to the establishment of the Aluminous Ferruginous Latosols as a new great soil group, which includes soils having high concentrations of gibbsite. Bauxite soils are of widespread occurence in the tropics, being reported in northern Australia, Borneo, Belgian Congo, Fiji, India and Jamaica.

Mohr (23), in describing the genesis of soils in tropical regions, gives special emphasis to the magnitude and distribution of rainfall, internal drainage of the soil, and age or duration of exposure to soil forming processes. Mohr recognizes five groups of rainfall distribution, based on the number of months per year receiving an average rainfall of less than 60 mm (classed as dry months) and the number of months averaging more than 100 m (classed as wet months). The rainfall groups comprise periods in which most months are classed as dry ranging to periods in which most months are wet.

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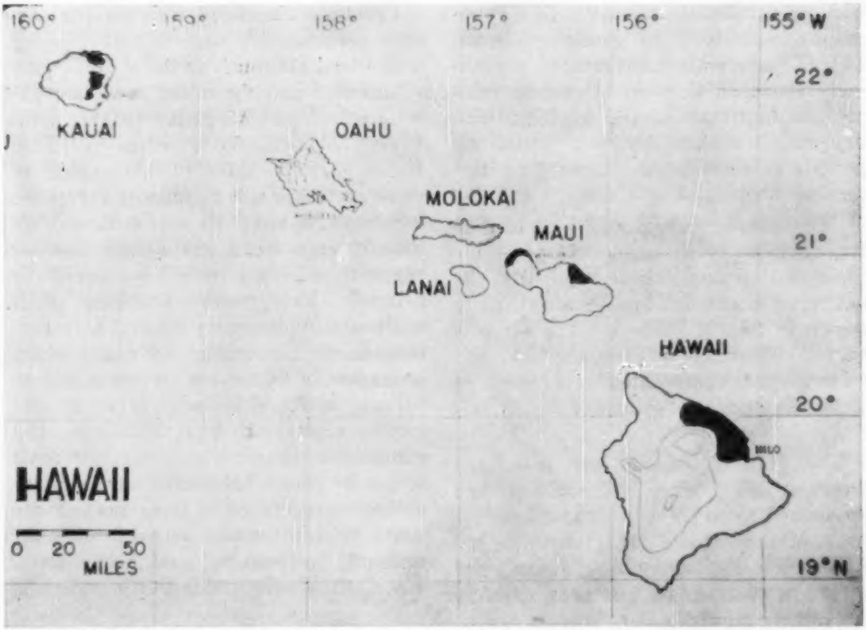

Fig. 1. Dark map areas show the general distribution of bauxite ores in the high rainfall areas of Hawaii. On Kauai and Maui the ores are gibbsite in kaolin and ferruginous clays developed on lava. Island of Hawaii ores are gibbsite-allophane clays developed on volcanic ash.

These groupings coincide with periods in which the weathering zone of the soil is alternately wet and dry, but predominantly dry, to periods in which the soil zone is continually wet and never dry. The low rainfall periods reduce the incidence and intensity of the agencies of weathering and thus the subject soils are relatively young and the constituent clays are chiefly montmorillonite.

The soils of the intermediate rainfall groups are more weathered than soils of the foregoing low rainfall areas, and the clays have transformed to kaolinite and to hydrated free oxides such as goethite. In the areas with high rainfall, typically the tropical rain-forest, in which the soil is constantly wet, the clays have weathered and degraded to hydrated free oxides such as limonite (Fe) and gibbsite (Al). Sherman (29, 30) has shown that under Hawaii conditions where the parent materials are commonly melilite and nepheline basalts low in silica, severe weathering under prevailingly wet conditions and good internal drainage has favored the progressive leaching of more mobile elements leaving behind bauxitic surface layers with up to 80 percent gibbsite, the remainder being chiefly iron and titanium compounds.

Conditions for Formation of Bauxites

The origin and formation of bauxites has been described by Harder (13), Goldman and Tracey (10), and Sherman (30), dealing respectively with world deposits, Arkansas, and Hawaii. They independently arrived at the conclusion that the conditions for bauxite formation are as follows: (1) Parent rock that weathers readily and which is high in aluminum content. (2) Soil material

with good internal drainage. (3) Topography with level to gentle gradients. (4) Climate with temperatures prevailingly above 25°C. (5) Abundant rainfall and high rate of soil leaching, with dry periods of short duration. (6) Long periods of time for the controlling factors to interact.

The above conditions for bauxite formation apply in various parts of the State of Hawaii and have resulted in the extensive areas of low grade bauxite shown in Fig. 1, Table 1. The deposits vary considerably in their chemical and mineralogical composition as a result of differences in the formative conditions (32).

The Hawaii bauxites are associated with ten soil families. A small acreage is devoted to sugar cane production, but most of the bauxite areas are marginal for commercial agriculture because of their low productivity and presently furnish inferior grazing, or lie idle.

History of Rehabilitation of Stripmined Areas

The literature on rehabilitation of stripmined areas on a world-wide basis is fairly voluminous. However, most references deal with restoration of stripmined coal areas and in general they are concerned with reforestation (1, 4, 5, 8, 19, 21, 28, 34). A few reports are concerned primarily with forage revegetation (7, 11, 19, 27, 35, 36).

Problems associated with spoil apparently are more acute where coal-stripping is involved inasmuch as the spoil is quite voluminous and the mined areas are extensive: West Virginia 40,000 acres (1940); Iowa 5,000 acres (1952); U.S.A. 225,000 acres (1947). Most of these spoils are able to support vegetation immediately after their formation, although large areas may remain bare or support only weeds unless sowed or planted. Revegetation problems occur where the spoil carries up to 3 to 5 percent oxidizable sulfur materials, which on exposure to the air are converted to sulfuric acid. The acid is toxic and further reacts with iron, aluminum, and manganese converting them to toxic forms for plants. Remedial measures are delayed revegetation of from one to three years, which permits removal of some toxicants by leaching, and heavy treatments with liming and fertilizer materials.

In general the coal spoils reported above require phosphorus, and nitrogen fertilization, sometimes potassium. Heavy liming is considered too costly on the toxic spoils, while moderate treatment is only of temporary value. In West Virginia delaying revegetation one to three years, followed by liming up to 5 tons per acre, and fertilization with NPK has permitted adequate forage growth. Century old iron-strip spoils in West Virginia, on which natural forage and forest revegetation has occurred, indicate that

TABLE I

VOLUME AND DISTRIBUTION OF HAWAII BAUXITE ORES[1]

Location of deposit, island	Area of deposit	Weight of ore[2]	Estimated average depth	Estimated content of aluminum oxide	Estimated volume of aluminum oxide
	Sq. miles	Tons/Ac. foot	Feet	Percent	million tons
Kauai	15	1000	30	33.3	96
Maui	15	1000	20	40.0	77
Hawaii	300	500	20	20.0	384
TOTAL	330	—	—	—	557

[1]G. D. Sherman. 1958. Gibbsite-rich soils of the Hawaiian Islands. Hawaii Agricultural Experiment Station Bulletin 116, pp. 23.

[2]Assumed bulk density of deposits for Kauai and Maui is 0.7, and for Hawaii 0.35.

the spoil is more productive than the undisturbed control. In some states, such as Missouri, Kansas, Kentucky, and Tennessee, little organized effort has been made to revegetate stripped lands, and apparently natural revegetation is adequate to prevent damage or loss of resources in nearly level areas under moderate rainfall. It should be noted that many of the mined lands are non-agricultural or marginal to start with and have little market value.

Results of revegetation of stripmined bauxite lands in Jamaica, commenced in 1953, are of special interest because of the similarity of climate to that of Hawaii (17, 19). Early results indicate that return of surface soil, at least six inches deep, distributed evenly over the stripped surface, is highly beneficial in revegetating and protecting denuded areas. Also there are unsolved problems associated with the utilization of the waters and the red mud following alumina extraction (Bayer process).

Commercial Potentials of Hawaii Bauxites

Some concept of the impact on the Hawaiian economy by commercial exploitation of the bauxite deposits may be derived from Table 1. From a ready-made commercial standpoint, the Kauai deposits appear to have the highest merit because of acceptable depth and distribution, high aluminum concentration, and ease of extraction. The Maui bauxite deposits are thinner, but otherwise similar to those of Kauai. Most of the gibbsite in these areas occurs as aggregates of crystals which range in size from that of single crystals to aggregates several inches in diameter. It is probable that the gibbsite can be concentrated by conventional processes involving drying and wet sieving. The rejects are chiefly ferruginous clays which may be returned to the strip-mined area or otherwise utilized as fill in low coastal areas. The reject ore also has a further potential value as a source of titanium and iron metal. In general the Kauai and Maui deposits occupy flats or ridgetops with gentle gradients. The aluminum concentration is highest at or near the surface, including the topsoil, and diminishes irregularly with depth. The concentration is also extremely variable laterally. Thus the rich ores may be intruded and interlarded by lean ores in an apparently random fashion. Currently the ores of commercial value must contain in excess of 35% alumina (Al_2O_3), generally above 50%. On this basis the Hawaiian bauxites are low-grade ores inasmuch as the bulk of the deposits range below 50% alumina concentration.

The most extensive bauxite deposit and about two-thirds of the total tonnage of ore in the state occurs along the Hamakua or northern coast of Hawaii at an average of about 20 feet in depth. These deposits average only about 20% alumina and are therefore too lean to warrant extraction using established methods. The soil materials in these deposits are continually wet and therefore the gibbsites occur as colloidal gels and not as crystals or aggregates. Simple drying and wet screening of the ores gives a low yield of concentrate, and is uneconomic. New extractive procedures therefore need to be developed to mine the Hamakua deposits economically.

Vegetation of Bauxitic Areas

Studies of vegetation on aluminous tropical soils have been made in Australia-New Guinea by Webb (37) and in Jamaica by Howard and Proctor (17). The study of the Australia-New Guinea flora was principally concerned with the determination of levels of aluminum accumulation in the species concerned and the phylogenetic implications of accumulation. Others, Chenery (2); Hutchinson (18); Moomaw, Nakamura and Sherman (24) have studied the accumu-

lation of aluminum in plants in general (and in Hawaii) and have concluded that aluminum accumulator species show a tendency to occur on acid, leached soils in humid tropical environments.

In Jamaica, Howard and Proctor (loc. cit.) studied the flora of mined bauxite soils and adjacent areas and concluded that no species could be named as characteristic of bauxite soils and that none of the species found on adjacent areas could not grow on aluminous sites. They found few species that accumulated aluminum and decided that most of the plants were unaffected by soil aluminum content or were tolerant of high levels. Moomaw, Nakamura and Sherman (loc. cit.) determined aluminum levels in plants grown in soils of known aluminum content in Hawaii and found several species (especially grasses) that had not previously been reported as aluminum accumulators. They found, in addition, plants classed as "excluders" which maintained remarkably uniform aluminum contents on soils varying widely in concentration of the element.

Hawaii Bauxite Land History and Use

Most of the bauxite lands are owned by the state and by a few plantations. Also, most of the lands are marginal for commercial agriculture, and either lie idle or provide poor grazing. The pasture production is inferior because of low soil fertility and yield, with forage low in palatability and nutritive value. However, research has shown that treatment wth adequate amounts of lime and fertilizers and planting of improved species will produce forage of superior quality. At present the pastures are used for the breeding herd and cannot fatten cattle except when improved pasture species such as pangolagrass, kikuyu grass or napier grass are grown.

Very little of the land is in plantation crops at present, allegedly because the high degree of cloudiness over the area retards sugarcane production and the excessive moisture limits the yield and quality of pineapple. Since the climate is prevailingly moist, the control of diseases, insects, and weeds is difficult. Shrubby weeds are a major source of trouble in pastures and little of the area is used for vegetable crops or fruit production.

The land use history of the Wailua Game Reserve area of Kauai, the site chosen for field vegetation experiments on stripmined soils, illustrates past and present marginal land use. It is a story of neglect and abuse, with a relatively recent attempt at improvement through reforestation and game-food planting. The primeval vegetation was almost certainly forest but the composition of the forest is difficult to reconstruct after nearly 200 years of sporadic agricultural use by European and American settlers. The 900 to 1000 years of Hawaiian settlement prior to European discovery had relatively little effect on the area since their settlements were normally confined to the beaches and the broad open valleys at low elevations. No remnant of terraces or native artifacts were encountered in the Game Reserve and such important native food plants as breadfruit, cooking banana and ape' (*Alocasia macrorrhiza*) were absent.

The three major influences in the history of the Hawaiian flora were: (1) the arrival of the Hawaiians with their food plants and limited cultivation, (2) the introduction of European agriculture, forestry (especially the sandalwood trade) and cattle about 1790, and (3) the continued introduction of useful and weedy plants that have readily naturalized in the Islands. Especially the second and third of these influences have had a major effect on the Hawaiian vegetation in all ecologic areas and have led to the replacement of the indigenous vegetation to a major degree, Degener (6, 25).

The vegetation of most of the alumin-

ous areas falls in the vegetation zone D_2, stated by Ripperton and Hosaka (26) to have been originally forested. The dominant tree was the ohia lehua which now mostly has disappeared and its place taken by the more aggressive guava (*Psidium guajava*). Ferns such as false staghorn (*Dicranopteris linearis*),[1] amaumau (*Sadleria cyatheoides*), Boston fern (*Nephrolepis exaltata*), and the tree fern (*Cibotium chamissoi*) are numerous. The screw pine (*Pandanus spp.*), and kukui or candlenut tree (*Aleurites moluccana*) are abundant in some areas and the joee (*Stachytarpheta cayennensis*) is a weed of common occurrence. Open areas are common and are dominated by grasses, sedges, herbs and several of the smaller ferns mentioned above. Hilograss (*Paspalum conjugatum*), ricegrass (*Paspalum orbiculare*), yellow foxtail (*Setaria geniculata*) and a few others are found, and carpetgrass (*Axonopus affinis*) and rattail grass (*Sporobolus capensis*) are becoming more widespread. Sedges (*Cyperus spp.*), Asiatic pennywort (*Centella asiatica*), sensitive plant (*Mimosa pudica*), and tarweed (*Cuphea carthagenensis*) are among the usual herbs.

The date of the first destruction of the forest cover on the Wailua Game Reserve is difficult to place. Certainly since World War 1, the area has been repeatedly burned and at least lightly grazed. From 1918 to 1939, a major part of the area was leased as public grazing land. Prior to that period it had been Forest Reserve. No pasture improvements were made, other than fencing, and it is known that carrying capacities were low.

In 1939 the Wailua Game Refuge was created and management of the area was turned over to the Division of Fish and Game of the Territorial Board of Agriculture and Forestry. Grazing was immediately prohibited and some attempts were made to improve the cover and food supply for introduced species of game birds. During World War II, the Refuge was requisitioned for the duration by the Military for a training area and was used for maneuvers, bivouac, and as an artillery range. Coral sand was brought in for camp sites and many of the ridges were travelled by military vehicles. The higher areas were used as the impact area for artillery practice which caused repeated fires. The lower, drier parts were more easily fired than the higher parts but even on the slopes of Mt. Waialeale to the west, where the annual rainfall exceeds 250 inches, the burned snags of *Metrosideros* trees of 18-inch diameter testify to fire.

About ten years ago, the Board of Agriculture and Forestry planted a test of seedling macadamia nut, Norfolk Island pine, and the varietgated screw pine trees. Some of the trees have survived and are making slow growth indicating no great promise by these species under existing natural conditions. On a plot of about one acre size, pigeon pea (*Cajanus cajan*) was planted after plowing, liming with about 500 pounds of crushed coral and fertilizing with 150 pounds of superphosphate per acre. The effect on plant growth of this moderate treatment is still visible on aerial photographs and can be seen on the ground from a distance of about a mile.

Vegetation Composition and Changes on Kauai Bauxite Lands

In the Wailua Game Reserve, three principal vegetation associations are encountered, only one of which bears any resemblance to the supposed original type. First, the ridges and south slopes of the ridges are covered with an association dominated by yellow foxtail and ricegrass, with substantial amounts of glenwoodgrass (*Sacciolepis contracta*), joee, lantana (*Lantana camara*), and ground orchid (*Spathoglottis plicata*).

[1]Synonym: *Gleichenia linearis* Clarke.

Fig. 2. The second association, the north-facing, situated on the slopes and lower portions of both sides of the ridges is codominated by foxtail and boston fern (*Nephrolepis exaltata*), and includes considerably more lacefern (*Stenoloma chinensis*), asiatic pennywort (*Centella asiatica*), and much less elephantopus (*Elephantopus mollis*) than the first type. The third vegetation type is found in the gulch bottoms and moist places, (Fig. 3) exclusive of the pure dense stands of the false staghorn fern (*Dicranopteris linearis*) which occur on the lower slopes. This riparian community is dominated by the common guava, with the lauhala (*Pandanus odoratissimus*), mountain apple (*Eugenia malaccensis*), and candlenut or kukui (*Aleurites moluccana*) frequently present in the overstory. The trees and rocks in this moist habitat support numerous epiphytic species of lichens, mosses, liverworts, and ferns as well as climbing vascular plants. The ground cover is made up of ferns and grasses which alternately predominate. Frequently occurring species are: *Phlebodium aureum, Elaphoglossum reticulatum, Athyrium microphyllum, Dryopteris dentata, Blechnum occidentale,* and others. The lianes include a native *Peperomia* and *Dioscorea bulbifera.* The awa'puhi (*Zingiber zerumbet*), a *Lobelia,* and *Sida acuta* occur with some regularity in places where drainage is good. The ground cover is *Oplismenus hirtellus* (Basket grass) in the open shade of the dominant guava.

The present composition of the plant cover in the Game Refuge and in general on aluminous soils in Hawaii has been brought about by man through a com-

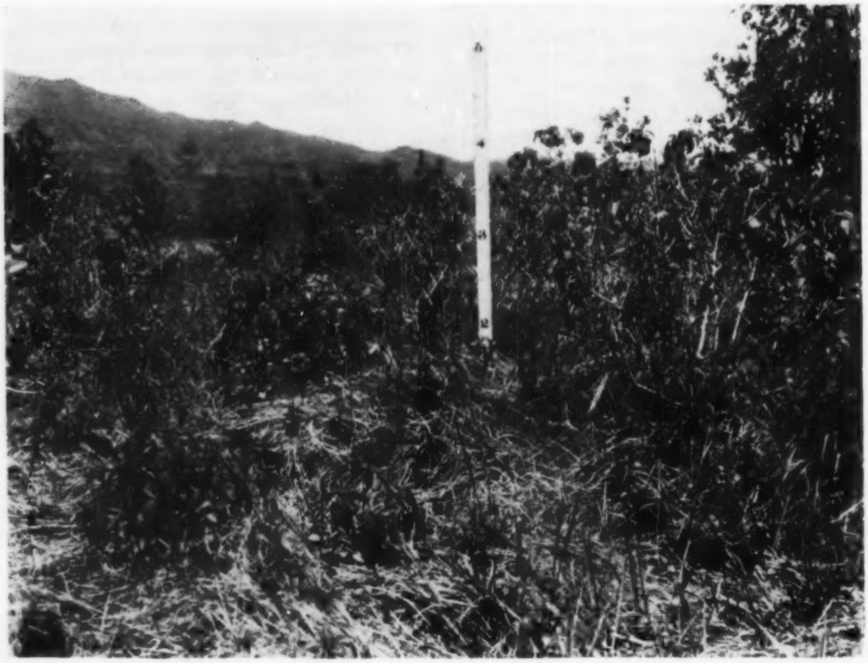

Fig. 2. Ridgetop vegetation showing vigorous shrubby growth of *Lantana* and deep litter of rice grass and yellow foxtail. (Photo by M. Takahashi)

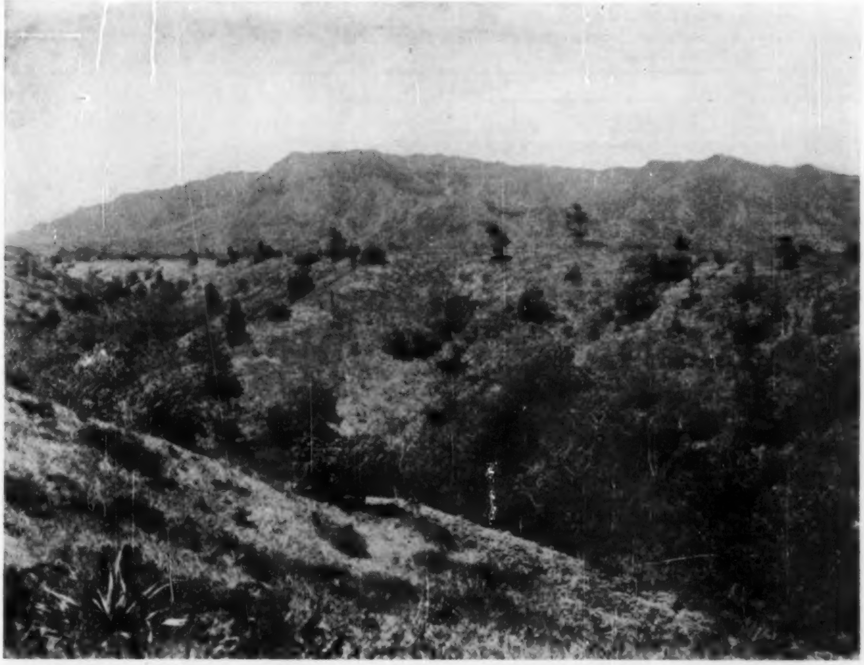

Fig. 3. Vegetation of protected gulches and ravines is principally guava and screw pine. Open ridges have scattered Java plum, *Grevillea* and *Casuarina*. (Photo by M. Takahashi)

bination of fire, grazing, agriculture and the introduction of useful and weedy plants that have become naturalized. In areas abandoned from plantation culture on Maui in the economic depression of the 1930's, a vegetation type similar to the Kauai site was examined but in less detail. In both instances a low successional stage is evident.

An opportunity to examine the effects of recent fire on the vegetation was afforded at the Game Refuge site when a series of controlled burns were made by the Division of Fish and Game, after the initial studies of the vegetation were completed. Many of the original transects and traverses were re-examined about eight months after the fire. This length of time allowed most of the species to mature and it was assumed that the vegetation at that time reflected conditions in the first season following fire. Species cover and frequency was tabulated and the species were classed as "increasers," "decreasers," and "little affected" by firing. The principal results of this census are shown in Table 2.

Land Preparation and Revegetation of Kauai Stripsoil

As noted elsewhere in this report, field departments of the Hawaii Agricultural Experiment Station received financial support to investigate the soil, water, and plant problems resulting from bauxite mining. The Kauai deposits were selected for study because they were considered of commercial quality and were receiving detailed attention by mining interests. Field operations were started in the bauxite deposits on Kauai, some five miles inland from the mouth of the Wai-

TABLE II

THE EFFECT OF CONTROLLED FIRE ON THE POPULATION OF PLANT SPECIES AND GROUND COVER OF BAUXITE SOILS EIGHT MONTHS AFTER FIRING, WAILUA, KAUAI, 1958.

Decreasers	Increasers	Little affected
Stenoloma chinensis	Bare soil	*Paspalum orbiculare*
Melastoma malabathricum	*Emelia sonchifolia*	*Sacciolepis contracta*
Setaria geniculata	*Cassia leschenaultiana*	*Nephrolepis exaltata*
Lantana camara	*Pteridium aquilinum*	*Stachytarpheta cayennensis*
Psidium cattleianum	*Chrysopogon aciculatus*	*Psidium guajava*
Spathoglottis plicata		*Elephantopus mollis*
Paspalum conjugatum		*Centella asiatica*
		Passiflora foetida

lua River, at an elevation of about 600 feet. The area comprises a series of long, narrow flat ridges separated by deep canyons extending to depths of 200 feet or more below the ridges. Commercial grade bauxite occurs on the ridges varying in depth to about 30 feet, with concentrations of gibbsite decreasing with depth. The steep-sided gulches contain no bauxite, the grassy vegetative cover of the ridges extends down the upper slopes and gives way to fern and guava thickets at the bottom.

In March, 1958, bulldozer operations were started at the test site for the removal of ore from some six acres of ridge top required for field experiments. The material was pushed into the adjoining gulches, stripping being continued until the ore assayed less than 30% Al_2O_3 on the dry basis. The main body of ore removed ranged in depth from 6 to 16 feet, beveling out at the edge of the ridge. The topsoil, prevailingly 6 to 10 inches in depth, including the herbaceous cover, was stripped separately and stockpiled for return as surface cover to the stripsoil,[1] if needed as an aid in restoring vegetative growth. After ore removal was completed, the stripped area was disc plowed and disced several times. The tractability of the substrate and the ease with which it attained a satisfactory state of tillage, was rather unexpected. The parent rock, solid and massive in appearance, crumbled readily under heavy tillage machinery.

Fertility Experiments

The revegetation of stripsoil[1] or bauxite substrate will depend in part on the ready availability of plant nutrients in the soil. Likewise the stripsoil is potentially deficient in several other factors, both physical and chemical. It would of course be desirable to convert the denuded areas directly to a protective vegetative cover to minimize run-off and at the same time arrive at economic crop production. Because of the unpromising physical and chemical status of the stripsoil, planting directly in the bare stripsoil could meet with failure, (Fig. 4). Accordingly, it might be necessary to return the native topsoil to the stripsoil to secure satisfactory revegetation. Replacing the topsoil would deprive the miner of the bauxite fraction in the topsoil, increase labor and costs, and therefore should be avoided if practicable. To gain information on these problems fertility tests were established.

After the test site had attained a suitable state of tillage, fertilizer and soil amendment experiments were laid down on the bare stripsoil with less than 30% Al_2O_3, and on stripsoil to which topsoil had been returned to a minimum depth of eight inches. In this series of tests, heavy doses were applied of all elements

[1]Stripsoil is the term given to the subterranean earth material left after removal of the overburden of spoil and ore. The new surface material is not subsoil in the pedological sense, nor is it parent material, inasmuch as it has been modified by severe weathering and leaching.

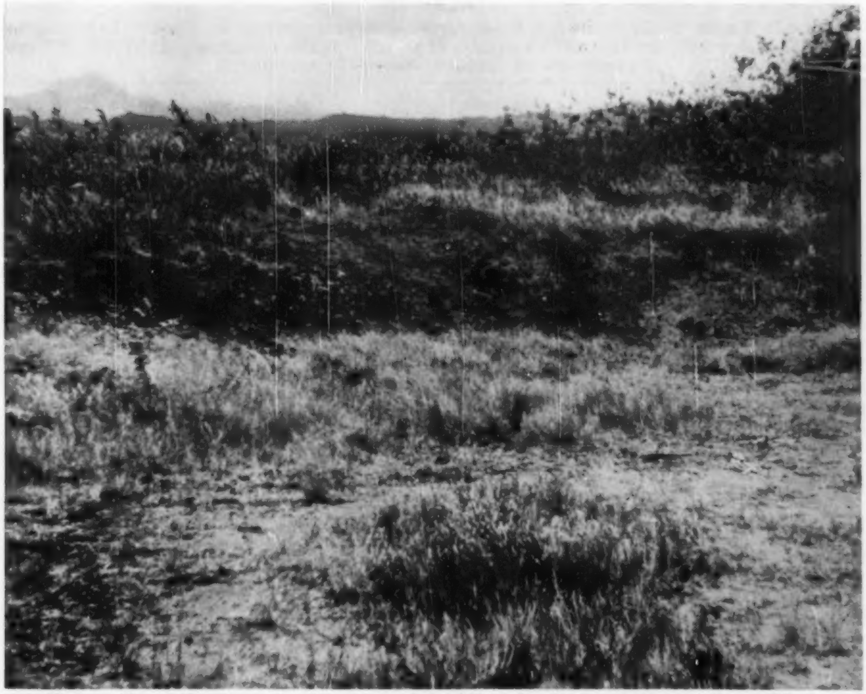

Fig. 4. Kauai bauxite stripsoil excavated in 1924, showing poor revegetation without soil treatment over a 36-year period.

known or suspected to be deficient. Lime was added to shift the soil reaction from about pH 5.0 in both topsoil and stripsoil to pH 6.2. This required 5000 pounds per acre of $CaCO_3$ for the stripsoil and 10,000 pounds for the more highly buffered topsoil. Ground coral rock was used as source of lime. Later it was discovered that the topsoil had been contaminated with coral sand by a World War II military facility. The no lime plots had pH 5.7, a reaction change requiring about 7000 pounds of lime. Because of the lime contamination, the response to liming in the topsoil test would be expected to be inconclusive.

Fertilizer grade materials were used as the source of fertilizer. Three mulches were utilized in the tests: Mill run bagasse, the fibrous waste sugarcane by-product remaining after extraction of the cane juices; fresh grass material from areas adjacent to the test site; and red stripsoil brought in from a dry area near Lihue. The soil mulch was spread before seeding and the organic mulches after seeding. The test crops were two legume species planted from seed, intortum (*Desmodium intortum*) and kaimi clover (*D. canum*); and pangolagrass (*Digi taria decumbens*) cuttings, which were sprigged into the soil at a 3 x 10 foot spacing following the removal of the first crop of intortum. The results of one year's operation of the tests are shown in Tables 3 and 4.

The yield data indicate that the topsoil revegetated quite readily when fertilized with NPK. The lime applications depressed yields initially but later appeared

TABLE III

FIRST-YEAR YIELDS OF *Desmodium intortum* AND *Digitaria decumbens* ON TOPSOIL RETURNED TO STRIPSOIL (6 FT.-16 FT. BELOW ORIGINAL SURFACE), WAILUA, KAUAI, 1958-59.[1] (PLOTS RANDOMIZED IN BLOCKS, SEVEN REPLICATIONS.)

Crop number			1	2	5	2 to 5
Growing days			74	65	71	365
Harvest date			9/30/58	12/4	9/23/59	
Harvest stage, condition			Max. veget.	Max. veget.	Full veget.	Intortum (grass <5%)
Treatment			Dry matter, 70° C			
No.	Element	Lbs. per Acre	Pounds per acre			
A	Check	None	0	26	236	500[4]
B	NPK	200-300-300	1077**	2451**	2522**	13260**
C	NP_2K	P600	1532	2638	2407	13330
D	NP_2KL[2]	L5000	874*	2633	2673	14060
E	NP_2KL_2	L 10000	466**	2706	2924**	13710
(F)	NP_2KL_2Mg[3]	Mg25 + 100	640	2687	2682	13330
G	(F) BMo	B10, Mo2.5	486	2699	2397	13990
H	(F) Mn Zn[2]	Mn95, Zn25	1421**	2748	2615	14260
(N)	(F) BMoMnZn		1362	2499	2529	14360
J	(N) Fresh grass mulch	DM5000	1299	2798	2520	14580
K	(N) Bagasse mulch	DM5000	1021	2555	2816	14800
L	(N) Red soil 1" mulch	Cu. y. 134	1906	2749	2489	14650
M	(N) Mn2	Mn130	1183	2567	2538	14470
I	(N) L surface L, RP subsurface	Rock P1000	1439	2764	2509	14200
O	(N) 1st yr.[3]		1175	2670	....	14780
	2nd yr. (N)—(LMn), K_3	K900, (N)			2837*	
Mean			1059	2495	2446	13220
*LSD at 0.05 probability			549	397	297	1204
**LSD at 0.01 probability			728	527	393	1596
Response significant			+(NPK) (MnZn) −(L, L2)	(NPK)	(NPK), L2 (N)K3	(NPK)

[1]Test established July 18, 1958, on well-tilled soil. Fertilizers broadcast, disced in. Seed of intortum (*Desmodium intortum*) and kaimi clover (*D. canum*) broadcast, harrowed in. Mulches topdressed as per plan. Pangolagrass (*Digitaria decumbens*) sprigged in 3′ × 10′ following first crop. Note that topsoil contaminated with coral sand so check had pH 5.7, L_1 pH 6.5, L_2 pH 7.0. Stripsoil check had pH 4.8, L_1 pH 5.5, L_2 pH 6.6.

[2]Growth extremely slow on stripsoil until additional P300 broadcast October 1, 1958, to Nos. D to O, giving total P600 pounds/A. Also topdressed Mn70 on Nos. H to O and additional Mn35 on M. Intortum responded at once to additional P, no effect noted for Mn. No response on topsoil to additional P and Mn.

[3]Foliage color pale green. Broadcast Mg100 Aug. 5, 1959, Nos. F to O. No effect to Mg noted. Also topdressed (N)-(L Mn) with K increased to K3 (K900 pounds/A) on No. O. Immediate response by pangolagrass which tended to suppress intortum.

[4]Check yields contain about 50 percent intortum and 10 percent kaimi clover, the remainder being mostly valueless yellow foxtail and mimosa. Kaimi clover is a significant component only of the check vegetation.

to be beneficial. On an annual yield basis, however, only NPK (200-300-300 pounds per acre) produced a statistically significant yield increase. It will be noted also, that a satisfactory vegetative cover was obtained on the topsoil almost from the start and that a satisfactory economic crop was obtained at the end of 20 weeks from establishment, as shown by the yields of the second ratoon.

Yields of forage in the stripsoil test, however, were slow to establish except where a grass mulch or a red soil mulch was utilized. It was found that the tilled stripsoil dried and crusted at the surface very readily and that this retarded and reduced seedling emergence from the small-seeded legumes used in the test. The grass and red soil mulches kept the surface fairly moist and promoted seed-

TABLE IV

FIRST-YEAR YIELDS OF *Desmodium intortum* AND *Digitaria decumbens* ON BAUXITE STRIPSOIL (6 FT.-16 FT. BELOW ORIGINAL SURFACE), WAILUA, KAUAI, 1958-59.[1] (PLOTS RANDOMIZED IN BLOCKS, SEVEN REPLICATIONS.)

Crop number			1	2	5	2 to 5
Growing days			74	65	69	365
Harvest date			9/30/58	12/4	9/23/59	
Harvest stage, condition			Veget.	Veget.	Full veget. (grass <10%)	Intortum (grass <10%)
Treatment			Dry matter, 70° C			
No.	Element	Lbs. per Acre	Pounds per acre			
A	Check	None	0	0	297	480[4]
B	NPK	200-300-300	16	897	2021**	7160**
C	NP_2K	P600	58	1924*	2734	11930**
D	NP_2KL[2]	L5000	0	1208	3136	12660
E	NP_2KL_2	L 10000	0	352	3788**	12510
(F)	NP_2KL_2Mg[3]	Mg25 + 100	0	265	3489	12810
G	(F) BMo	B10, Mo2.5	0	372	3126	12210
H	(F) MnZn[2]	Mn95, Zn25	0	884	3271	12760
(N)	(F) BMoMnZn		0	864	3337	13490
J	(N) Fresh grass mulch	DM5000	285	3505**	2571	14040
K	(N) Bagasse mulch	DM5000	0	613	3177	12290
L	(N) Red soil 1" mulch	Cu. y. 134	139	3032*	2667	14260
M	(N) Mn2	Mn130	0	716	3692	12690
I	(N) L surface L, RP subsurface	Rock P1000	8	1908	3028	13350
O	(N) 1st yr.[3] 2nd yr. (N)—(LMn), K_2	K900	0	593	—— 4365**	13410
Mean			34	1156	2993	11800
Yield ratio substrate/topsoil, %			3	46	122	89
*LSD at 0.05 probability				1859	768	2340
**LSD at 0.01 probability				2596	1018	3102
Response significant				(NP_2K); fresh grass, red soil mulches	(NPK) L_2 (N)K_2	(NPK), P_2

[1], [2], [3], & [4] For footnotes, see Table 3.

ling growth. However, a bagasse mulch which also kept the surface moist apparently was of no value in plant establishment or as an amendment. A related test on rates of phosphorus on sudangrass grown on stripsoil showed that maximum response occurred at about P 1000 pound per acre, and was reasonably satisfactory at P 500 and above. On this basis the original P treatent in the current test was too small. Accordingly, all plots D to O received an additional topdressing of P 300. The response to the additional P was immediately apparent in ratoon 2, and by ratoon 3 the yields were satisfactory. The stripsoil yields obviously were much lower than the topsoil yields at the start but rapidly improved. By ratoon 5 or at the end of the first year the stripsoil outyielded the topsoil.

Based on the rapid establishment of dense growing crops with yields equal or superior to topsoil returns, it is evident that stripsoil culture as such is satisfactory. It is apparent, however, that the stripsoil culture requires a phosphorus treatment of about P 600 pounds per acre compared to P 300 for the topsoil. Other nutritional elements such as N, K, Mg and lime probably will be required equally by both types of soil culture. Also, it is evident from the check yields that establishment of a vegetative cover without the treatment of fertilizers meets

with failure on both types of culture (Fig. 5).

It is planned to continue cropping the tests on the stripsoil, and stripsoil with topsoil returned in order to arrive at the long term effect of the two types of culture.

Vegetation Experiments on Kauai Stripsoil

Field tests on crop adaptation on denuded soils were initiated soon after the test site was ready for experimentation. A long list of accessions of agronomic, horticultural and arboreal interest were tested for adaptability on the stripped soils (Fig. 6). The major portion of the work has been confined to the stripsoil with topsoil returned, which received lime at the rate of about 5000 pounds per acre and a heavy basic fertilizer treatment including all elements suspected to be deficient in the soil for crop production. However, in some instances trials are being conducted on adjacent areas of natural soil for the purpose of comparison. It should be stressed that heretofore economic crops have invariably made poor growth and have been considered failures in this soil area.

In the crop adaptability trials, the standard plantation crops, sugarcane and pineapple, are being grown on both unstripped soil and stripsoil with topsoil returned. Both crops apparently are making satisfactory growth on the mined soil when receiving adequate fertilizer treatment. The tests on tilled unstripped

Fig. 5. Kauai stripsoil responds to heavy treatments of complete fertilizer, requiring 200-600-300 (NPK) pounds per acre at the start (right). Unfertilized stripsoil when tilled and planted remains barren (left).

Fig. 6. *Eucalyptus punctata* on fertilized and limed topsoil returned to stripsoil. The seedlings, two feet at the start, reached a height of 16 feet in one year.

areas, using plantation practices, show the usual poor crop performance, indicating that stripping of the soil to depth in itself is not a practice calamitous to economic crop production. However, final appraisal and verdict must await harvests of the plantation crops, 20 to 24 months from planting.

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BOOK REVIEWS

Plant Pathology, an Advanced Treatise. Vol. 2. The Pathogen. Edited by J. G. Horsfall and A. E. Dimond. 715 pp. Illus. Academic Press, New York, 1960. $22.00.

This book is the second of a three-volume series on plant pathology, compiled and edited by Horsfall and Dimond. Eighteen authors from 14 institutions involving five countries collaborated in writing the book. Each writer is a competent scientist in his field. Good editing and logical organization of material plus a high caliber of writing by the various contributors also add considerable stature to the volume. Because the book is made up of contributions from 18 authors the style is obviously not uniform. This variety of styles makes for more interesting reading.

The first volume of the series is centered on the diseased plant. In the present volume the stress is on the cause of disease and on host-pathogen relationships. Therefore, considerable emphasis is given to the physiology of pathogens and diseased plants. The book consists of 15 chapters. The first chapter, a prologue written by the editors, is a general discussion of concepts and causes of plant disease. Many agents that cause plant disease are discussed but algae and higher plants are omitted. The second chapter, by G. L. McNew, is devoted to the nature, origin, physiology, and evolution of parasitism. An excellent review on the multiplication of viruses is presented by F. C. Bawden in Chapter 3. In Chapter 4 Lillian Hawker describes in considerable detail the nature and method of reproduction in bacteria, actinomycetes, and fungi. And in Chapter 5, V. W. Cochrane reviews factors that influence spore germination. Chapter 6, by S. Dickinson, and Chapter 7, by R. K. S. Wood, embrace topics on mechanical and chemical ability of microorganisms to breach the host barrier. Chapter 8, on the interaction of soil, pathogens, other microorganisms, and the host, was written by T. S. Sadasivan and C. V. Subramanian. A critical review on toxins from bacteria and fungi in relation to pathogenicity is presented in Chapter 9 by R. A. Ludwig. The next two chapters are devoted to genetic variation in microorganisms: E. W. Buxton gives a comprehensive historical review on the role of heterocaryosis, saltation, and adaptation in production of new races and biotypes in fungi; and T. Johnson summarizes concisely the importance of mutation and hybridization in production of new entities in pathogenic fungi. In Chapter 12 R. E. F. Matthews reviews inactivation of bacteria. H. D. Sisler and C. E. Cox ,in Chapter 13, and S. Rich, in Chapter 14, emphasize importance of physiology and chemistry of fungicides, respectively. The last chapter, by M. W. Allen, although entitled nematocides, treats also of plant diseases caused by nematodes.

An immense amount of scientific material has been crowded into this work. Each chapter is an excellent and comprehensive treatment of the subject. All the articles are well documented, and references are conveniently grouped at the end of each chapter. This background of material helps to make intelligible the more recent discoveries.

At the beginning of each chapter the important topics in the article are listed—a very useful feature. The subject index, which is adequate, is made up of important items from the text; cross references are numerous. An author index of all references cited is included.

The book should be most valuable as a reference work not only for pathologists and teachers but for biologists as well. The price of the volume is rather high, which may tend to limit circulation.

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Plant Pathology: An Advanced Treatise. Vol. 3, The Diseased Population, Epidemics and Control. Edited by J. G. Horsfall

and A. E. Dimond. 675 pp. illus. Academic Press, Inc., New York, 1960. $22.00.

This is the third and final volume of an advanced review of present knowledge concerning plant diseases. It is primarily an analysis of epidemics and their control. This volume is likely to be more interesting to the professional plant pathologist than are the other two volumes because most of the topics it covers have not been recently reviewed elsewhere.

In the first two chapters the editors and S. D. Garrett thoroughly review the present concepts of inoculum potential. Certainly this discussion is one of the most comprehensive treatments of the idea and significance of inoculum potential in print.

Chapters 3 through 6, which deal with dispersal of inoculum, constitute a scholarly treatise and are so well written that any interested person could learn much by studying them. Most plant pathologists, however, will gain most new food for thought from chapter 6, in which H. Schrödter suggests that the flight and landing of fungus spores are largely problems in physics, and thus he develops his discussion. His suggestions should stimulate more research in this relatively new but important field.

The remaining portions of the book deal with control of epidemics. The problems of disease forecasting, quarantines, control by means of cultural practices or of application of chemicals to soil and plants, the influence of various micro-organisms in arresting epidemics, and the development of disease-resistant crop varieties are all comprehensively presented by competent scientists, some of whom have international reputations.

Perhaps the most thought-provoking chapter in the entire three-volume work is J. E. van der Plank's "Analysis of Epidemics" (Chapter 7 in volume 3). The author attemps to be analytical rather than descriptive. Much discussion should be stimulated in phytopathological circles by that portion of the chapter where van der Plank develops the *r* concept, a statistic describing the various environmental factors that interact to permit epidemics to develop. Equally interesting is the consideration given to the influence of host-plant populations on the rise and fall of epidemics.

Each chapter contains a list of references on which particular ideas are based and which will help guide further study of the various topics. The book closes with complete but separate author and subject indexes.

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A Compilation of the Edible Wild Plants of West Virginia. William H. Gillespie. 1 + VII + 118 pp. Scholar's Library, New York, 1959. $2.50.

This thin volume consists of very brief accounts of the more than 350 species of vascular plants found wild in West Virginia that are judged by its author to be edible. Species of some of the genera included, e.g., *Quercus, Rosa,* and *Urtica,* are not dealt with separately because their suggested use is similar. The short treatment of each species or group typically consists of common and scientific names, data on habitat and very general distribution within West Virginia, date of availability, a word or so about one or more uses, and an additional brief note or two. There are approximately 48 full-page plates, each bearing four or five small figures illustrating as many species. These illustrations are taken from those prepared for the *Flora of West Virginia.*

Authors of works on edible plants generally fail to exclude those plants that are merely edible but that are certainly no treat. The author of this book is no exception. Many of the plants do not seem in the least tempting and offer little or no reward for the trouble expended to gather them. One would have to be perverse indeed to try the berries of *Streptopus,* which should be consumed "with caution," according to the author, and which are described in other books as a cathartic. Nor is there much to recommend the dried seeds of redcedar as a coffee substitute if the author's appraisal, "that they improve the water very little," is to be taken at face value. Furthermore it would appear advisable for the reader to postpone trying the "hardened milky juice" of milkweed as a substitute for chewing gum until someone else determines whether its reputation as a poison is warranted. A great many other plants are included merely as emergency foods. When all is said and done, and

for good reason, West Virginians will continue to rely upon grocery stores in spite of the long list of edible wild plants.

As a field guide for the West Virginia area, the book may find a limited use. However, for those interested in information concerning the past and present use of our native and naturalized plants as a source of food or beverage, I am afraid the book will prove a disappointment. Unfortunately, references are not given, and the reader who is introduced to this fascinating subject by the book will find in its pages no mention of the splendid *Edible Wild Plants of Eastern North America* by Fernald and Kinsey, a book that would provide him with some of the enchantment of the subject and with a first-hand account—lacking in the present volume—of many of the advocated uses.

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Maladies of Hevea in Malaya. Roger N. Hilton, with watercolors by Hoh Choo Chuan. 101 pp. Illus. Rubber Research Institute, Kuala Lumpur, Malaya, 1959. $30.00 (Malayan).

It is interesting to note that the *Hevea* rubber tree, a native of the Amazon Valley, was carried to the Orient and to Malaya in particular in the form of small seedling trees grown from Brazilian seed in the greenhouses of the famous Kew Gardens of England. There was thus provided an effective, although inadvertent, method of producing plants free of diseases and insects, an early example of a plant quarantine procedure that is now more or less regular practice. The result was that for some years Malayan rubber plantings were free of disease. The author records a statement by a local agriculturist, published in the *Agricultural Bulletin of the Malay Peninsula* some twenty years after the first plantings, to the effect that, "I have not noticed any enemy, animal or vegetable, attacking the tree."

This happy state of affairs did not long continue, for enemies soon appeared and became increasingly prevalent with the development of large scale plantings. The fungi involved were not introduced species but rather those that attacked native hosts and that developed the ability to attack the new host once it was available in large, continuous plantings. The result was that the planters were confronted with an increasing number of diseases requiring intelligent and concerted action to prevent serious losses.

The author and his associated artist present in this book an effective aid to this end. Forty-one maladies of various parts of the *Hevea* rubber tree as it grows in Malaya are described and illustrated. The diseases included are for the most part those due to fungi or to such non-parasitic causes as drought, flooding, soil deficiencies, faulty nutrition, and other physiological disturbances. A parasitic alga and certain mistletoes are also included. Particularly effective are the illustrations of the several fungus root-parasites that cause the most serious of the diseases involved. These fungi spread from adjoining jungle trees or from stumps left in clearing for the rubber plantations. Insect pests are not included, and surprisingly enough no virus or bacterial diseases are known on the rubber tree in Malaya.

A page of text accompanies each of the color plates, describing symptoms, cause, other plants affected, manner of spread, prevention, and treatment for each disease under consideration. The presentation is brief, authoritative, and largely non-technical. The aim is to provide the planter with the information essential for him to learn the symptoms of the diseases that threaten his trees and to enable him to take the necessary steps to prevent or control their development. The book should serve its purpose well, due in particular to the excellence of the water color illustrations.

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Die Acker- und Grünlandleguminosen im Blütenlosen Zustand. Adolf Stählin. 162 pp. illus. DLG-Verlag, Frankfurt am Main, 1960. DM 8.80.

The stated purpose of this book is to aid identification of non-flowering, non-fruiting specimens of the most important legumes used in central Europe for fodder, human food, stock feed, and green manure. To this end, Dr. Stählin, who is Director of the Institut für Grünlandwirtschaft und Futterbau at Giessen, has provided a 23-page key,

based wholly on vegetative characteristics, to 101 species and subspecies in 28 genera, all of which belong to the subfamily Papilionoideae; detailed descriptions of roots, stems, and leaves of these plants; and line drawings to illustrate distinguishing features of the plants. An introductory chapter discusses the use of vegetative characteristics in identification of legumes. Genera represented in the book by most taxa are, as might be expected, *Lathyrus, Lotus, Lupinus, Medicago, Melilotus, Trifolium,* and *Vicia.* The drawings, regrettably amateurish, seem especially poor in comparison with the carefully prepared descriptions. Following each description is a brief resumé of occurrence and uses of the species. The worth of the key can be demonstrated only after considerable trial but I can record that alfalfa, chick pea, white sweet clover, soybean, and kidney vetch can be "keyed out" admirably. Among the few woody plants included in the book are *Sarothamnus scoparius, Ulex europaeus,* and members of *Genista.*

Dr. Stählin's book, which is of handy size for carrying in the field, is a refreshing departure from the usual emphasis on the use of flowers and fruits in plant identification. Works devoted to identification of economic plants—or of *any* plants—in vegetative condition are few. Their chief purpose is to assist determination of specimens collected of necessity before flowering time or from sites where grazing or mowing prevent appearance of flowers. *Die Acker- und Grülandleguminosen im blütenlosen Zustand* can be expected to serve this purpose well.

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Northwest Ethiopia: Peoples and Economy. Frederick J. Simoons. xvii + 250 pp. illus. The University of Wisconsin Press, Madison, 1960. $5.00.

Recently two other books on Africa were reviewed in *Economic Botany: Manioc in Africa* (Vol. **14** 2, 1960) and *Africa* (Vol. **14** 3, 1960). I feel that *Northwest Ethiopia* is another important book on an African subject. The book is especially valuable as a survey of a part of Ethiopia which has been by-passed by modern travelers and authorities.

The author is assistant professor of geography at the University of Wisconsin, and the book is his doctoral dissertation. Professor Simoons studied under Dr. Carl Sauer at the University of California, in one of the most productive schools of cultural geography.

Northwest Ethiopia is a dissected plateau, bordered on the north by the Tekezzay River and on the south by the Blue Nile. Although modern access is limited and difficult, in the past many different races invaded, occupied, and left their influence on the country and its present population.

Practically no industry exists in the province of Begender and Semyen, and almost all endeavor is agricultural. Seed crops are the major concern of the northwest Ethiopian, and very few vegetable or root crops are grown. One of the more interesting and valuable grains raised in the province is t'eff (*Eragrostis teff*). Professor Simoons discusses this crop in more detail than other grains (sorghum, maize, wheat, barley, pearl millet, etc.) because of its uniqueness as a cultigen. Ethiopia is almost the only country in the world where t'eff is important. In addition to the grain crops, inhabitants of northwest Ethiopia place heavy emphasis on the pulses, various oilseeds, spices, stimulants, and aromatics. Although coffee is not grown in the area, there is a great demand for it. A measure of the difficulty in communications with other areas is the fact that coffee imported from southern Ethiopia takes some thirty days to reach the market at Debre Tabor. Ch'at (*Catha edulis*), whose leaves are chewed to provide a stimulant, is used largely by Moslems. It is raised on a large scale in Harar and is one of the few exports from the area, being transported by air to the Aden market.

Most of the crops raised originated in the Old World, but a few New World crops have become of great importance. Of all the spices, *Capsicum frutescens,* a New World import, is by far the most used in local cookery.

Another fascinating, though less important crop is the ensete (*Ensete edule,* formerly *Musa ensete*). This species has been used widely as an ornamental, but only in Ethiopia is it considered as a food crop. Actually, ensete is more important outside of the area under discussion, and only small quantities are raised in northwest Ethiopia.

Simoons has presented arguments for and against the origins of various crop plants in Ethiopia. Certainly the country is an ancient agricultural center, but many of the arguments are geographic, cultural, and/or utilizational, and these are frequently misleading. Much more botanical research is needed to "prove" that any crop was first cultivated in a particular region. Archeological evidence is very important in determining origins of cultivated plants. It is scarce for early cultivation in Ethiopia. Many such records come from nearby Egypt, and these may or may not apply to Ethiopian cultivars.

Professor Simoons spent eight months in northwest Ethiopia in 1953-54, four months in other parts of Ethiopia and several additional months in the Sudan, Uganda, Congo, and Nigeria. His work, therefore, is especially significant because of his close touch with the many aspects of life in northwest Ethiopia. He has organized the book in encyclopedic fashion, taking separate chapters for physical description; historical background; peoples, social and political organization; settlement and house types; agriculture; cultivated plants; animal husbandry; fishing, hunting, and food gathering; food, cooking, and nutrition; crafts and industries; marketing and trading; and conclusions.

The most displeasing part of the book is the very poor layout and printing. The effectiveness of maps, drawings, and photographs is greatly reduced by miserable reproduction. All photographs are center-bound, making reference to them difficult.

DAVID J. ROGERS
The New York Botanical Garden

A Concise Encyclopedia of World Timbers. F. H. Titmuss. 264 pp. illus. The Philosophical Library, Inc., New York, 1959. $15.00.

This book describes briefly the characteristics, uses, and gross structure of 224 woods and purports "to form an indispensable addition to the libraries of the many firms and individuals whose livelihood depends on the growing, the distribution, or the use of timber." The title will be somewhat misleading to American readers because the book is with few exceptions limited to timbers of various parts of the British Empire. It is interesting to note that only about 50% of the woods found in the book appear on the American market. Conspicuously lacking, so far as the American market is concerned, are such important woods as cativo (*Prioria*), bubinga (*Guibourtia*), avodire (*Turraeanthus*), angelique (*Dicorynia*), and many others. The well-known zebrawood of American commerce is the product of *Microberlinia*, which is not mentioned in the text. Reference is made, however, to the little known *Pithecolobium racemiflorum* and *Connarus guianensis* as being zebrawoods, although wood of the latter is of no commercial importance.

The introduction of 16 pages covers growth of the tree, structure of hardwoods and softwoods, naming of timbers, method of developing an identification key, and some definitions of terms used in the text. The remainder of the book (pages 25 to 254) is devoted to description and identification of the various timbers, which are arranged alphabetically from abura to zebrawood. Many descriptions are very brief. Each wood has a page devoted to it alone, resulting in much wasted space that could profitably have been utilized by addition of species that have grown in importance during the last ten years. The reader may become dismayed by the fact that after each description he is referred for fuller data to other publications, some of which may be difficult to find in his locale. Most of the 30 low-power photomicrographs in the text are excellent but others are rather poor reproductions of the intended woods and might just as well have been omitted. Although the author does not claim the bibliography to be complete, he has omitted some important and newer sources of information. It is interesting to note that while Solereder's *Systematic Anatomy of the Dicotyledons* is mentioned, the newer and more comprehensive *Anatomy of the Dicotyledons* by Metcalfe and Chalk is absent. Other noteworthy omissions are *Atlas des Bois de la Côte d'Ivoire* by Normand, *Atlas Anatomique des Bois du Congo Belge* by Lebacq, and reference to the tremendous fund of information to be found in the journal *Tropical Woods*. The reader may be surprised to find *Hymenaea courbaril* described on two different pages under both courbaril and West Indian locust and that (page 200) "The *Betulus* [*sic*] species, how-

ever, do not occur in the Southern Hemisphere." It is apparent that *Fagus* was meant here rather than *Betula*. A few relatively minor nomenclatural and typographic errors occur in the book. It is unfortunate that the coverage of *A Concise Encyclopedia of World Timbers* is so limited. Undoubtedly the high price of the book will deter many a potential buyer.

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An Introduction to Ethnobotany. P. J. Faulks. vii + 152 pp. Moredale Publications, Ltd., London, 1958.

Ethnobotany is as difficult to define as is economic botany. Neither term may be applied precisely to a particular type of research, study, or synthesis. In spite of this, almost anyone may picture some activity that could be called ethnobotany. It is likely that most people would consider ethnobotany to be the study of the relations of primitive man to the plants he used or uses.

Professor Faulks makes very clear in *An Introduction to Ethnobotany* that this definition is only a part of his view of the subject. All the multitudinous connections, direct and indirect, between man and plants are the proper field of ethnobotany.

This little book is one of the best discourses on the basic dependence of man on plants, their parts, their products, and their activities. Professor Faulks uses only examples of some of the plants that play a role in a particular setting; he does not pretend that the book is a compendium of all plants used for fiber, drugs, etc. He presents not only a good exposition of ethnobotany but also some very refreshing new ideas about man and plants.

Faulks frequently shows connections of plants with the languages we speak. For instance, in Chapter VII, "The Provision of Shelter and Protection," (page 30) he speaks of parts of dwellings: "Of these, doors were developed first and oak has for a very long time been favoured for door construction because of its great strength. The Sanskrit name for 'oak' is 'dwr,' and from this the English, Latin, Creek, German and Hebrew names for 'door' have all been derived. 'Durmast' is a trivial or common name of the English oak."

One might object to the many short chapters of the book which seldom go past three, four, or five pages of text. Each chapter is a separate essay, but continuity is achieved by grouping them by parts: I. "Goods and Services Obtained from Vegetation"; II. "Troubles Caused by Vegetation"; III. "What Man Does to Vegetation"; and IV. "Vegetation and Civilization." The reader is given only a short introduction to a particular subject, a little exposition, and then the subject is dropped in favor of another. Yet, I cannot object too strenuously here, because as I have thought about various chapters, their content and possible extensions of exposition, I cannot honestly add much more in the same line of thinking.

Any professor of general botany, trying to convince his students that the study of botany is valuable, vital and interesting, could get new arguments here for his introductory lecture. A layman would enjoy knowing of his debt to plants, and many practicing ethnobotanists have not thought of the many connections between man and vegetation.

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Diseases and Pests of Ornamental Plants. 3rd ed. Pascal P. Pirone, Bernard O. Dodge, and Harold W. Rickett. x + 775 pp. illus. The Ronald Press Company, New York, 1960. $10.00.

The value of this work needs no emphasis for those already familiar with the first two editions. Dr. Pirone, successor to Dr. Dodge at The New York Botanical Garden, is largely responsible for the latest edition. For those not familiar with the earlier editions, this is one of the most useful compendia on diseases and pests of ornamental plants grown outdoors, under glass, or in the home. The first part of the book explains in sufficient detail the knowledge necessary to understand plant diseases, the kinds of organisms that are pathogens or pests on plants, and the methods of control.

In Part II, the host (ornamental) plants are listed alphabetically by their scientific names, with good cross references to common names. The most frequent diseases and their symptoms are given for each plant, with control recommendations. The text is of outstanding technical accuracy, but it

may be used with ease by any interested layman. Sufficient illustrations are included to show various types of fungus infection or insect damage, and sufficient explanation is given to satisfy the need of the home gardener.

Information on plant diseases, new insecticides, and new fungicides has been growing at a phenomenal rate since the second edition (1948). So many competing products are on the market that the home gardener is frequently confused concerning the proper treatment of his diseased plants. This treatise is helpful in associating the various chemicals and their trade names and in applying the correct treatment.

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Advances in Agronomy, Vol. 11. Edited by A. G. Norman. x + 428 pp. illus. Academic Press, Inc., New York, 1959. $12.00.

This volume, like its predecessors, was prepared under the auspices of the American Society of Agronomy. Each of the sixteen contributors is a well-known scientist in the subject he covers. The book is divided into six major sections. Five are reviews with extensive bibliographies. The sixth, "Soils and Land Use in the Netherlands" by P. G. Meijers, is a survey of soils, land use, and changing crop patterns of that country. In terms of its inherently productive soils, the Netherlands has limited resources. Dutch soils have been raised to a high level of productivity through development and adoption of intensive agronomic practices.

"Water and its Relation to Soils and Crops" comprises one-fourth of the volume. M. B. Russell and his collaborators have thoroughly reviewed the literature on this complex subject and have compiled a most useful bibliography. A discussion of the physical nature of water is followed by an exhaustive treatment of the hydrologic cycle. Plant-water relations and soil-plant-water interrelations are well handled, with emphasis on the continuity and dynamics of water through the entire soil-plant-atmosphere system. Is soil moisture equally available for plant growth over the range from field capacity to permanent wilting? The answer to this question has been in dispute for many years. R. M. Hagan *et al.* point out the reasons for the dispute and suggest what kinds of information are needed to resolve it. Their treatment of the subject should be required reading for all students of plant physiology and of soil physics.

In "The Economics of Fertilizer Use in Crop Production" R. D. Munson and J. P. Doll define concepts and review past and present research. This complex and new subject, which is of increasing importance with the expanding use of fertilizers in the drive for maximum efficiency in crop production, has been well handled by the authors. Much checking and testing of the concepts and equations developed to date is yet to be done. Economic justification for heavy application of fertilizer rests on the interpretation of yield data in the light of these modern concepts and equations as economics of fertilizer usage. Therefore the review is especially timely.

The gamut of implements for tillage and seed bed preparation, seeding, cultivating, spraying and dusting, and harvesting is covered by T. W. Edminster and H. F. Metler, Jr. in "Recent Developments in Agricultural Machinery." The rapid development and increased use of agricultural machinery in recent years make this an especially interesting subject. The reader comes to realize that fantastic machinery specialization is a prime factor in the agricultural revolution of today. For example, mechanical harvesters for crops such as cucumbers, castor beans, and tomatoes illustrate the ingenious application of invention to save labor and increase efficiency of production.

K. D. Jacob, in "Fertilizer Production and Technology," reviews developments that have taken place in this field since the 1949 review in *Advances in Agronomy*, Vol. 1. Statistics are presented to show fertilizer and plant nutrients consumption internationally and in the United States. The author describes methods of production and sources of raw materials for all elements used in fertilizers and discusses mixed fertilizers and mixtures of fertilizer and other agricultural chemicals.

In "Effect of Nitrogen on the Availability of Soil and Fertilizer Phosphorus" D. L. Grunes considers first the biological effects of nitrogen on uptake of phosphorus by plants. Among these effects are the greater

vigor, greater plant size, and greater root efficiency that result from an ample nitrogen supply. The complementary ammonium ion effect, stage of plant growth, and the nitrogen effect on plant metabolism are also considered. Salts and pH are discussed under chemical effects of nitrogen on uptake of phosphorus. The interrelationships of biological and chemical factors involved in the effects of nitrogen on the uptake of phosphorus are well illustrated.

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British Parasitic Fungi. W. C. Moore. xvi + 430 pp. Cambridge University Press, New York, 1959. $8.50.

Regional compilations of pathogenic fungi are enormously valuable to plant pathologists and mycologists. Moore's book is a welcome and most useful addition to the field. This volume differs considerably in scope and treatment from some other regional works. It covers only cultivated plants, unlike the U.S.D.A.'s *Index of Plant Diseases in the United States* or Shaw's *Host Fungus Index for the Pacific Northwest*. However, it is much more informative within its scope because it includes key references to many organisms and also frequent brief discussions. Indeed, the treatment of major pathogens may run to several pages with sections on biology, losses, forecasting, spraying and dusting, etc. The book thus provides a fine introduction to the British literature on plant diseases.

The body of the book is in two sections, of which the first is an alphabetical listing of the host plants. Major species are treated separately, and common names are cross-indexed to scientific names. The second and much longer section is an alphabetical listing of the fungi together with important synonyms. Here the reader can quickly find the British distribution and host range of a fungus, and, if the fungus is of particular significance, considerably more information. Space inevitably limited the references that could be cited, and naturally almost all references are to British publications. Perhaps this policy might have been waived more often with some benefit. I notice a number of instances where reference to recent work on the taxonomy or biology of a fungus would have materially assisted the reader.

The nomenclature of the fungi is avowedly conservative. This is a sound policy, but the author occasionally follows it to the extent of using invalid names. Thus the names of several powdery mildews and a few rusts are not in accordance with the rules. Most of these errors could have been avoided by following the lists of W. B. Cooke and of Cummins and Stevenson, respectively. In a different category is the question of species concept. In general, the author seems to have followed a narrow concept, e.g., *Puccinia cichoriae* and *P. endiviae* are treated as species distinct from *P. hieracii* despite lack of any morphological distinction. In contrast, some distinct species are lumped, e.g., *Pucciniastrum epilobii* is used to include *P. pustulatum* from which it differs in its aecial, uredinial, and telial morphology as well as in its hosts. However, no two authors would agree fully on the nomenclature of all the fungi listed, and the slightly uneven treatment detracts little from the usefulness of the book.

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Forage Management in the Northcentral Area. D. Smith. 154 pp. illus. Wm. C. Brown Book Company, Dubuque, Iowa, 1960. $3.25.

This is a well-organized and carefully-documented compilation of material relating to the culture and use of the major perennial forages sown for hay and pasture in northcentral United States. The author explains plant reactions in terms of physiological and ecological causes and effects, and this explanation helps the student understand the basic principles involved in such reactions. The reactions are related to culture and management in such a way as to tie them into a unified whole.

The first chapter is a brief introductory statement about the area, its historical development of forage crops, and about the major grasses and legumes now used there. Chapters 2 and 3 discuss seeding, establishment, and survival of these crops, chiefly from an ecological standpoint, while the next three chapters emphasize physiological

aspects. Chapters 7 through 12 cover the principal legumes, major emphasis being given to alfalfa, the most widely used one. The chapters on legumes are followed by three on management that cover green manures, seed production, and growth responses. The next four chapters treat Kentucky bluegrass, smooth brome, timothy, orchardgrass, and reed canarygrass in detail. The last two chapters deal with pasture renovation and grazing management.

Each of the abundant and well chosen references emphasizes some point clearly and concisely. References are listed at the end of each chapter and are chosen to give historical and developmental background as well as recent interpretation. Readers and researchers seeking further and more detailed information along the lines covered in this book should have no trouble "entering" the field of literature at nearly any point.

The author states that the book grew from mimeographed sheets first used in the 1930s in the forage management course taught at the University of Wisconsin. It has been expanded to keep pace with the rapid development in this and related fields. Thus, the subject matter covered and the materials used represent the areas needed by students. The book is organized in such a way that each topic leads logically to the next.

The typographical and grammatical errors that appear might easily have been eliminated by closer attention to editing. The writing in the first three chapters tends to be wordy and somewhat awkward in places. In the chapters that follow, the wording is freer, easier, and more concise. Chapter 6 contains an especially clear and easily-read description of plant nutrition and growth in terms that apply to forages and forage management, from both the historic and the modern aspects.

There is a strong tendency to interpret plant repsonses only in relation to conditions that exist in the cooler and more humid portions of the area and to omit mention of the differences found farther south and west. For example, the seeding of perennials along with companion crops are seldom used in the drier parts of the area. Seeding and establishment also are discussed from the same standpoint. The problems encountered in the drier parts should be covered also.

Natural or range pastures are omitted entirely, although these make up the bulk of the grazing land in the Dakotas, Nebraska, and Kansas. Temporary forage crops such as the small grains, lespedeza, certain sorghums, etc., also are left out.

Despite the few drawbacks mentioned, *Forage Management in the Northcentral Area* is a noteworthy volume, one that all students of forage crop culture must see and use, and one whose applications are not so geographically limited as the title may suggest.

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Abbreviations. **A.** = abstract; **Art.** = article; **B.R.** = book review.

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